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SOMMAIRE

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UN PROBLÈME DE MORPHOLOGIE ARIDE : "LES PEDIMENTS"

PAR

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I. DÉFINITION ET THÉORIES

1) Définition.

Au pied des grandes chaînes plissées du Tertiaire s'étendent généralement des plaines formées par l'accumulation, dans des dépressions, d'une partie des débris arrachés à la montagne par l'érosion. Au débouché des vallées s'étalent des glacis d'alluvions, des *piémonts*.

Les *pediments*, par contre, sont des plaines d'érosion, des glacis rocheux sans manteau alluvial important s'étendant aux pieds des montagnes dans les pays arides ou sub-arides (pl. I).

Un pediment est un glacis rocheux avec un profil longitudinal concave où la roche en place affleure même parfois sur une largeur de plusieurs kilomètres. Ce profil concave est nettement relevé au contact de la montagne.

Le pediment normal a généralement une surface très régulière à pente plus ou moins masquée par un mince manteau de débris et accidentée seulement par des collines éparses s'élevant d'une façon abrupte au-dessus d'elle. Ce sont des reliefs résiduels appelés souvent « *inselberge* » (pl. II).

La pente de 3 à 4 % au contact de la montagne se réduit à 1 % à la limite extérieure de la plaine. Elle « s'aplatit de plus en plus lentement à l'aval et passe insensiblement à une plaine alluviale très doucement inclinée — La *bajada* (ou *bahada*) des auteurs américains — qui, dans

les bassins fermés, aboutit à une nappe d'eau temporaire, «*sebkra*» ou «*playa*»» [1].

Si des pediments ont été reconnus notamment dans le Sud-Ouest des Etats-Unis [2], au pied du Grand Atlas de Marrakech [3] et autour des montagnes de l'Asie Mineure [4], il en a été également reconnu au Sinaï. E. de Martonne [5] et l'auteur [6] ont signalé l'existence, au pied du Gebel Oum-Alaoui, d'un véritable glacis rocheux, parfaitement aplani, recouvert d'une pellicule détritique mince et grossière, et accidenté de bosses en saillie qui sont, en tous cas, des reliefs résiduels (pl. I).

2) Théories.

Trois processus géomorphologiques au moins ont été suggérés pour expliquer la formation de pediments. Ce sont : l'action du ruissellement en nappe (*sheetflood* ou *sheetwash*), l'érosion latérale des cours d'eau à leur débouché de la montagne et le recul des versants dû principalement aux intempéries [7].

On a beaucoup discuté pour savoir quel est le processus déterminant. Trois théories s'opposent pour expliquer le recul du front montagneux en pays arides : la théorie de l'érosion latérale, celle de l'érosion par nappe de ruissellement (*sheetflood*), et enfin celle du «Back-Wearing» c'est-à-dire dégagement d'un pediment par recul du versant montagneux

(1) Baulig (H.), *Essais de géomorphologie,* Paris 1950, 161 p., v. p. 80.

(2) Mc Gee (W. J.), *Sheetflood Erosion, Bull. Geol. Soc. America,* t. 8, 1897, p. 87-112.

(3) Dresch (J.), *Recherches sur l'évolution du relief dans le Massif Central du Grand Atlas, le Haouz et le Sous.* Tours, Arrault 1941, xx + 708 p.

(4) Chaput (E.), *Contribution à l'étude géologique de la Turquie, B. S. G. F.,* t. 5, 2, 1932, p. 9-16.

(5) De Martonne (E.), *Reconnaissance géographique au Sinaï, Bull. Soc. Géogr. d'Eg.,* t. XXII, 1948, p. 105-136.

(6) Awad (Hassân), *La Montagne du Sinaï central, Etude morphologique. Publ. Soc. géogr. d'Egypte,* Le Caire 1951, x + 247 p.

(7) Sur l'ensemble du problème voir A. C. Cotton, *Climatic Accidents in Landscape-Making,* 1947, chap. iii, iv, v et vi, et Ben A. Tator, *Pediment Characteristics and Terminology, Ann. Assoc. Amer. Geographers,* 1952, p. 295-317 et 1953, p. 47-53.

sous l'action de la désagrégation et sous celle du ruissellement en nappe déblayant les débris.

a) *La théorie de planation latérale :*

Les partisans de cette théorie affirment que les pediments sont formés par planation latérale des cours d'eau à leur débouché de la montagne. S. Paige [1] admet que le processus de l'érosion latérale des cours

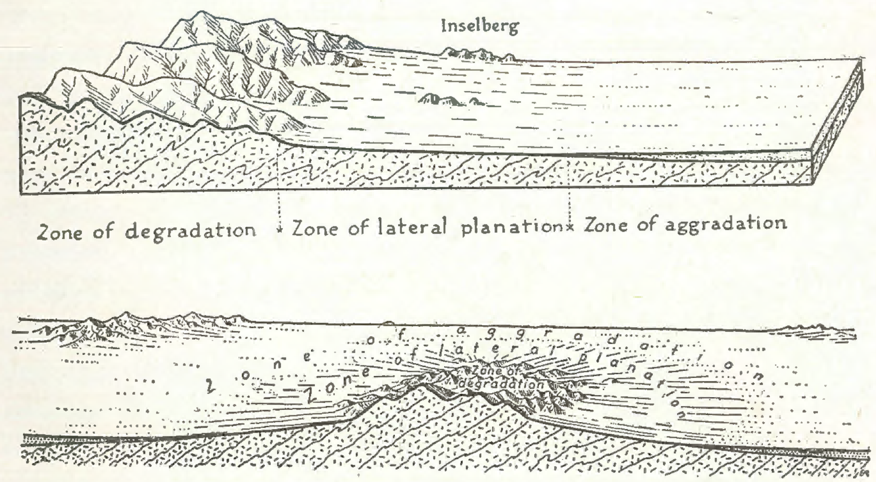

Fig. 1. Schémas de la formation de pediments d'après D. Johnson.

d'eau peut produire une surface rocheuse aplanie doucement inclinée vers l'aval, surface qui peut être enterrée vers le centre d'un bassin sous une couverture graveleuse. Selon lui l'érosion en nappe de ruissellement (*sheetflood*) est plutôt le résultat du développement de cette surface aplanie que sa cause.

Mais c'est D. Johnson [2] qui développe en grand cette thèse appuyant ce processus de planation. Il croit que dans les régions arides où les montagnes sont situées près des bassins intérieurs ou les encerclant,

(1) Paige (S.), *Rock-Cut Surfaces in the Desert Ranges, Jour. Geol.,* 20, 1912, p. 442-450.

(2) Johson (D. W.), *Rock Fans of Arid Regions. Ann. J. Sc.,* 233, 1932, p. 389-416 : *Rock Planes of Arid Regions. Geogr. Rev.,* vol. 22, 1932, p. 656-665.

il existe trois zones distinctes qui sont : a) zone intérieure composée essentiellement de montagnes dans lesquelles l'érosion verticale par des cours d'eau est dominante; b) zone extérieure correspondant à une plaine alluviale très doucement inclinée — la « *bajada* » —, zone dans laquelle l'alluvionnement prédomine; c) une zone intermédiaire, entre les deux, en avant du front montagneux, dans laquelle l'érosion latérale et le transport affectés par des cours d'eau sont dominants (fig. 1). Selon D. Johnson, c'est dans la zone intermédiaire que la pedimentation prend place.

Du côté de la montagne le pediment pénètre sous forme de golfes (*embayments*) que D. Johnson a appelés « *rock fans* » : cônes rocheux. Ces surfaces rocheuses en forme de cônes correspondent chacune à un débouché d'oued. Les pediments dérivent donc de ces formes, et leur pente ainsi que leur étendue sont conditionnées par l'importance de leurs oueds. Pediments et *rock fans* sont attribués à un seul processus d'érosion celui de planation latérale des cours d'eau fortement chargés de matériaux à leur débouché de la montagne [1].

Un rôle important a été attribué au déplacement des oueds à travers les cônes là où ils quittent la montagne. Ce déplacement n'est pas celui des cours d'eau à méandres dans une plaine alluviale mais il est plus comparable au changement que subissent les cours d'eau quand ils se divisent en une multitude de filets anastomosés. Le résultat de ce déplacement répété est que les cours d'eau occupent de temps en temps des positions marginales par rapport au front montagneux.

Les objections les plus sérieuses qui s'opposent à la théorie de l'érosion latérale sont : 1°) la rareté des « *rock fans* » exposés sans manteau détritique; 2°) les « *sheetfloods* » ont plus d'importance que les cours d'eau comme processus d'érosion dans les régions arides; 3°) il serait difficile d'expliquer l'aspect rectiligne généralement présenté par le front montagneux si son recul avait été opéré par l'érosion latérale : il aurait fallu alors que le front montagneux ait un tracé sinueux avec des rentrants importants là où les cours d'eau principaux débouchent de

[1] LEFEBVRE (M. A.), *Note sur les Pediments du désert Mojave (Californie)*, *Bull. Soc. belge d'Etudes géogr.*, t. XXI, 1952, p. 259-268.

la montagne; 4°) les buttes ou les chicots résiduels qui sont très souvent observés sur la surface des pediments sont incompatibles avec l'idée de planation latérale; 5°) la plupart des cours d'eau quand ils débouchent de la montagne et quand ils se divisent en bras et filets à travers les cônes n'empiètent pas sur le front montagneux. Les rentrants du front montagneux devraient avoir des angles plus larges que normalement observés si l'érosion latérale avait été aussi importante que l'on suppose.

Devant ces objections on hésite à donner à l'érosion latérale un si grand rôle comme facteur dominant dans la formation des pediments bien qu'il soit cependant difficile de nier son importance comme facteur contributif [1].

Il se peut toutefois que des pediments de cette forme et de cette origine existent, mais seulement dans les régions semi-arides. Il est difficile d'admettre une telle théorie pour expliquer les formes similaires dans les régions très arides à cause de l'absence de cours d'eau bien individualisés. Ce processus d'érosion latérale devient moins efficace avec une aridité croissante. Son rôle est minime dans les régions à relief faible aussi bien que dans celles élevées mais dont le relief est non disséqué c'est-à-dire là où les cours d'eau même intermittents deviennent des phénomènes rares.

b) *La théorie du sheetflood :*

Il est admis que les premiers pediments reconnus l'ont été dans le désert sonorien — « *Sonoran Desert* » — au Sud-Ouest de l'Arizona par Mc Gee en 1879 [2].

Il avait proposé le nom de pediment pour désigner ces zones d'aplanissement qu'il avait attribuées à l'érosion de « *sheetfloods* ». Mc Gee croyait que les *sheetfloods* ont une grande puissance de corrosion étant donné l'abondance de leurs outils et leur grande vélocité. Les pediments ainsi formés auraient donc tendance à mordre sur la montagne par des méthodes qui malheureusement n'ont pas été clairement expliquées par Mc Gee.

[1] THORNBURY (W. D.), *Principles of Geomorphology*, New York, 1954, 618 p.
[2] Mc GEE (W. J.), *Sheetflood Erosion*, *op. cit.*

Tandis que le ruissellement en nappe — quoique rare — soit la seule forme possible de ruissellement sur de larges étendues aux pieds des montagnes dans les déserts arides, le ruissellement concentré est par contre très localisé. Il est dû d'ailleurs aux conditions topographiques exceptionnelles.

Pour W. M. Davis [1] également, les pediments peuvent se développer par la seule action de la nappe de ruissellement « *sheetflood* », sans l'intervention de l'érosion latérale par des cours d'eau au débouché d'un versant montagneux. L'absence de rivières dans certains cas, le contact rectiligne de pediments autour de dômes isolés, sont opposés à une évolution liée à l'érosion latérale fluviale.

Ainsi nous arrivons à la dernière théorie, celle de recul du front montagneux sous la double action de la désagrégation météorique affectant les versants et celle du ruissellement en nappe déblayant les débris et à laquelle Davis avait donné le nom de « *Back-Wearing* ».

c) *Processus de Back-Wearing :*

Tout en admettant la possibilité de l'action érosive du ruissellement en nappe, Davis voit plutôt le travail principal de *sheetflood* dans le transport des débris provenant du versant montagneux. Ce transport s'effectue dans toute la traversée du glacis vers la « *bahada* ».

W. M. Davis a bien montré que le ruissellement est incapable de corrosion latérale quand il s'est ramifié en « *rills* » ou étalé en « *sheets* ». Aussi pour lui le versant montagneux recule-t-il spontanément parallèlement à lui même après avoir atteint un degré de pente déterminé notamment par le calibre des débris arrachés. Ce recul du versant montagneux aurait comme conséquence le dégagement, petit à petit, d'un plancher rocheux s'incorporant au pediment.

Pour H. Baulig, il est évident que « le versant ne peut continuer à reculer que si les débris qu'il produit sont déblayés à mesure : et cela est le fait du ruissellement provenant du versant lui-même et de l'inté-

[1] Davis (W. M.), *Sheetfloods and Streamfloods, Bull. Geol. Soc. America,* vol. 49, 1938, p. 1.337-1.415.

rieur de la montagne. Ce sont les mêmes processus, désagrégation et ablation qui s'exercent mais en proportion différente sur le versant et sur le glacis, en se conditionnant mutuellement » [1].

Il est juste de mentionner que le processus de recul de versants raides parallèles à eux-mêmes en laissant au devant d'eux un glacis rocheux a été traité synthétiquement par A. C. Lawson [2]. Ce dernier a essentiellement envisagé le cas de bassins fermés désertiques dont le niveau de

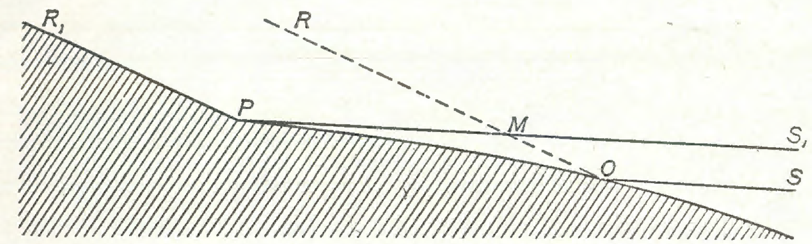

Fig. 2. Profil dessiné par A. C. Lawson pour illustrer sa théorie.
OS. et *PS.* : surfaces successives du glacis alluvial ;
OR. et *PR.* : profils successifs de front-montagneux. Le pied de l'escarpement s'est déplacé de *O* en *P* amenant la formation du glacis rocheux *OP* qui recouvre le glacis alluvial à mesure.

base devrait s'élever. Il en résulte que le remblaiement alluvial de ces bassins recouvre la surface rocheuse au fur et à mesure de sa formation au pied de l'abrupt (fig. 2).

La première particularité de ce glacis rocheux (*suballuvial bench* de Lawson) est donc sa disparition progressive sous le manteau d'alluvions. La deuxième particularité est le profil longitudinal de la surface de pediment qui est convexe vers le ciel.

La théorie de A. C. Lawson sur le recul des versants montagneux parallèlement à eux-mêmes a été adoptée par W. M. Davis. Toutefois la modification importante apportée par celui-ci est l'introduction de l'idée

[1] Baulig (H.), *Surfaces d'aplanissement, 2e Partie, Ann. de Géogr.,* LXI, 1952, p. 245-262 (v. p. 248).

[2] Lawson (A. C.), *The Epigene Profiles of the Desert, Univ. of California Publ., Bull. Dep. Geology,* vol. 9, n° 3, 1915, p. 23-48.

suivante concernant la nature de l'action de *sheetflood.* Pour Lawson le *sheetflood* est uniquement envisagé comme l'agent de transport. W. M. Davis le considère comme agent de dégradation et de transport surtout dans la partie amont et dans les stades tardifs [1]. Nous y reviendrons plus loin.

* * *

Il semble toutefois que les conditions géologiques (influences lithologiques en particulier) et climatiques aient pour conséquence une différentiation dans le degré de l'efficacité de trois processus.

II. INFLUENCES LITHOLOGIQUES ET STRUCTURALES

P. Birot considère que les pediments développés en roche tendre s'expliquent facilement par la théorie de D. Johnson : sapement latéral exercé par des cours d'eau saturés de cailloux de gros et moyen calibre. La théorie de W. M. Davis peut expliquer les pediments développés en roche dure mais sujette à la décomposition granulaire comme le granite. Ces derniers sont attribués au recul des versants par : 1°) l'action de la désagrégation météorique granulaire qui affecte les versants jusqu'à la base ; 2°) le déblaiement par le ruissellement en nappe des éléments ameublis et le dégagement à la base de la montagne d'une banquette rocheuse [2].

Des glacis rocheux, développés dans la bordure peu résistante de hautes montagnes plus ou moins arides ont été signalés au Hoggar [3], au pied du Grand Atlas marocain [4], au pied de l'Atlas Saharien, en

[1] Davis (W. M.), *Sheetfloods* and *Streamfloods, op. cit.,* v. p. 1.400.

[2] Birot (P.), *Sur le problème des origines des Pediments, C. R. Congrès Intern. de Géogr.* Lisbonne 1949, t. II, Sect. II et III, 1950, p. 9-15.

[3] Perret (R.) et Lombard (A.), *Itinéraire d'In Salah au Tahat à travers l'Ahaggar, Ann. de Géogr.,* t. XLI, 1932, p. 379-398.

[4] Dresch (J.), *Les surfaces du Piémont dans le Djebilet et le massif du Grand Atlas, C. R. Congr. Intern de Géogr.,* 1938, p. 133-140.

Mongolie [1] et au Sinaï [2]. Il est généralement admis que les pediments les plus répandus sont taillés dans des roches tendres [3] au pied d'abrupts de roches dures.

Il existe au Sinaï Central deux systèmes de côtes : au Sud la côte Crétacée du Gebel El-Tih et au Nord la côte Eocène du Gebel Egma. Au pied de la première se développe un pediment dans les grès nubiens. Ce pediment, quoique peu étendu, s'observe partout. Néanmoins nous avons remarqué que dans les rares endroits où l'escarpement du Tih dessine des amphithéâtres, d'ailleurs très ouverts, la régularité de la surface du pediment se trouve quelque peu détruite. Ceci est évidemment en rapport avec la convergence du ruissellement dans les amphithéâtres obséquents. On peut en effet noter assez souvent que les *badlands* se développent surtout dans les zones de divergence du réseau hydrographique [4].

D'autres glacis s'observent aussi en roches résistantes. Dans ce cas leur surface est généralement peu étendue. De plus le profil du pediment produit aurait une pente plus forte que normalement tandis que sa surface serait irrégulière. C'est le cas notamment des roches très résistantes à la désagrégation météorique comme les quartzites. Les granites, roches grenues, par contre donneront des profils très réguliers [5] (pl. III).

Notons enfin que la valeur du *knick* (rupture de pente entre le versant et la surface de pediment) est parfois en rapport avec la structure et la nature des roches. On doit s'attendre en effet à ce que le *knick* soit bien marqué lorsqu'il souligne une différence de structure ou de composition pétrographique. De plus les roches à joints espacés donneront les versants les plus abrupts augmentant ainsi l'angularité entre le glacis rocheux et le front montagneux.

[1] Berkey (C. P.) and Morris (F. K.), *Geology of Mongolia, Nat. Hist. of Central Asia,* t. II, 1927, p. 323-351.

[2] Awad (Hassân), *op. cit.,* v. p. 184.

[3] Des roches comme les schistes donnent de larges pediments tandis que les grès n'en offrent que de peu étendus.

[4] Birot (P.), *Sur le problème de l'origine des pediments, op. cit.,* v. p. 18.

[5] Baulig (H.), *Essais de géomorphologie, op. cit.*

La texture de la roche intervient également ici. Les roches grenues, comme les granites, livrent de gros blocs, maintenant ainsi la raideur du front montagneux (pl. II). Mais ces blocs ne sont pas résistants à la désagrégation et ils se décomposent en débris de faible diamètre faciles à évacuer. Le *knick* est dû à la plus grande rapidité de la désintégration sur les pentes faibles que sur les pentes raides [1] (pl. III et IV). Le contact entre le versant et le pediment est moins brutal quand la roche est très résistante à la désagrégation, fournissant des débris grossiers qui se déposent au pied de l'escarpement en talus d'éboulis. L'angle se trouve ainsi estompé ou recouvert d'un talus de débris qui le rend invisible.

Les variations lithologiques donnent souvent une surface irrégulière tout au moins aux stades de début. Les processus de pedimentation continuant pour un certain temps sont néanmoins capables de raboter les inégalités de la surface malgré l'hétérogénité des roches.

III. INFLUENCES CLIMATIQUES

Il serait souhaitable qu'une distinction, même arbitraire, fût faite entre pediments des régions semi-arides et pediments des régions arides. Trop de données manquent encore pour que l'on arrive dans ce domaine à une précision qui ne soit pas exagérément illusoire.

Toutefois on constate que l'érosion latérale ne s'exerce pas dans des conditions d'extrême aridité. K. Bryan [2] remarque en effet que les conditions favorables à l'action de l'érosion latérale sont réalisées dans les parties des déserts de l'Amérique du Nord qui ne sont pas extrêmement arides. L'action de l'érosion latérale est liée essentiellement à l'existence des chenaux individualisés ayant un débit suffisant, un lit d'une certaine dimension et importance, et transportant une charge de matériaux adequates à être utilisés dans l'abrasion.

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(1) Joly (F.), *Erosion en surface et érosion linéaire dans le modelé pré-désertique, 50e Anniv. du Lab. de Géogr., vol. jubilaire,* Rennes 1952, p. 255-267.

(2) Bryan (K.), *The formation of Pediments, Report XVI, Intern. Geol. Congress* 1935, p. 1-11.

Il faut bien souligner comme facteur majeur l'importance de la durée du ruissellement, parce qu'un écoulement même faible se poursuivant sur une longue période est plus efficace qu'un écoulement plus important mais concentré dans le temps, c'est-à-dire moins fréquent. Plus l'aridité est accentuée, moins les conditions sont favorables à une érosion latérale par des cours d'eau généralement éphémères et gonflés seulement durant quelques minutes ou quelques heures pendant et après les averses brutales et concentrées. Cette forme de ruissellement est d'après Bryan incapable de réaliser une érosion latérale efficace.

Les surfaces de pediments des régions semi-arides peuvent être expliquées par la planation des cours d'eau à leur sortie de la montagne. Mais il existe des surfaces de pediments dans des régions trop arides pour avoir un écoulement par courants (*streamflood*). Ici la forme normale de l'écoulement des eaux est celle de l'écoulement par nappes (*sheetflood*).

Le rôle du climat devient très important en rendant l'un des éléments de pedimentation prépondérant par rapport aux autres.

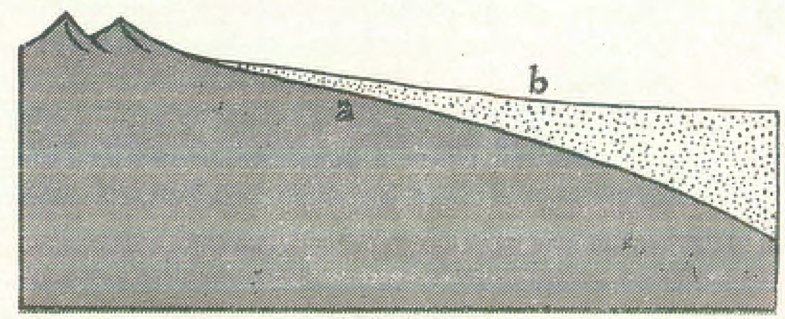

Fig. 3. *a*) Plancher rocheux convexe (*suballuvial bench* de Lawson).
b) Glacis alluvial à pente concave.

IV. PEDIMENTS ET NIVEAU DE BASE

Nous voudrions attirer l'attention sur l'influence des facteurs ayant trait au niveau de base dans l'évolution des pediments. Là où le niveau de base ne s'élève pas le glacis rocheux ne doit pas être enseveli sous les accumulations détritiques. Par contre dans les régions endoréiques, de drainage intérieur, et à niveau de base ascendant, la *bahada* tient une place prépondérante dans les stades de jeunesse et de maturité.

Dans ce dernier cas, le plancher rocheux serait enterré et enseveli progressivement sous les matériaux de remblaiement de la *bahada;* le profil de ce plancher serait convexe (fig. 3). C'est à cette forme que A. C. Lawson [1] avait donné le nom «*suballuvial bench*», surface formée par le recul du front montagneux sous conditions de niveau de base ascendant. D'après A. C. Lawson l'exhaussement du glacis alluvial ensevelit les parties amont du glacis rocheux (*bench*) en l'enterrant à des profondeurs de plus en plus grandes. A mesure que la surface de la *bahada* s'étendra, son niveau s'exhaussera de plus en plus lentement.

Il ne faut pas s'attendre d'ailleurs à une augmentation du volume des matériaux apportés de la montagne, il y aura plutôt diminution puisque le recul du front montagneux réduira en même temps sa hauteur. La pellicule alluviale s'amincit à mesure que la surface de remblaiement s'étend vers la montagne, en même temps que la pente de *suballuvial bench* devient de plus en plus faible dans la même direction. En d'autres termes la convexité du glacis rocheux décroît progressivement vers le haut du versant jusqu'à ce que sa surface se rapproche de celle de sa couverture détritique. Le profil prend donc la forme convexe hyperbolique.

Il s'ensuit que dans les régions d'un niveau de base ascendant le pediment se déplace vers l'amont en même temps qu'il s'étend par le recul du versant et que sa surface aussitôt formée par ce recul est recouverte par les alluvions qui y empiètent.

Si le niveau de base s'abaisse, la dénudation reprenant, un pediment apparaîtra et son apparition s'effectuera progressivement cette fois, de l'amont vers l'aval par l'enlèvement de son manteau détritique. La convexité du profil se transformera par l'action du ruissellement en une concavité normale (fig. 4).

Dans les régions à drainage exoréique les pediments développés par le recul des versants ne doivent garder leur profil convexe et leur couverture de débris qu'aux stades de début. Plus tard leurs surfaces seront exhumées et leurs profils deviendront concaves (fig. 5).

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[1] Lawson (A. C.), *op. cit.*

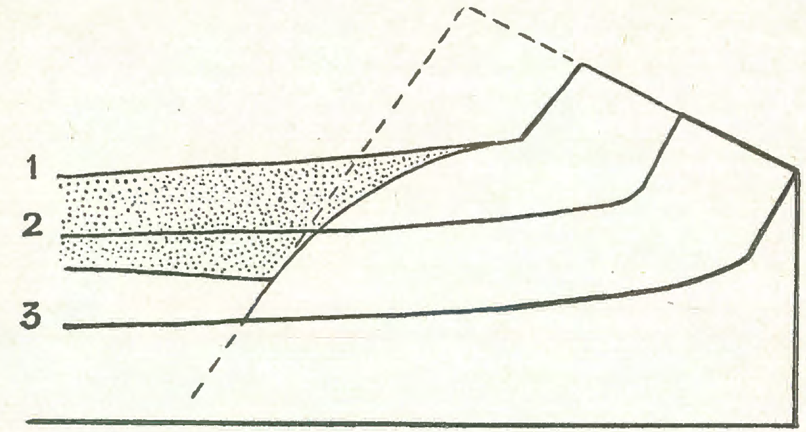


Fig. 4. Différentes formes de profils de pediments en rapport avec le niveau de base (d'après A. D. Howard).

1. Cas de niveau de base ascendant (bassin fermé) : le plancher rocheux est enseveli sous les débris arrachés à la montagne.

2. Cas de dégradation amenant le développement d'une surface tranchant à la fois la roche et le glacis alluvial.

3. Cas d'un abaissement de niveau de base : abaissement du profil de pediment et déblaiement de la couverture alluviale. Toute la surface est constituée uniquement par celle du pediment ou glacis rocheux.

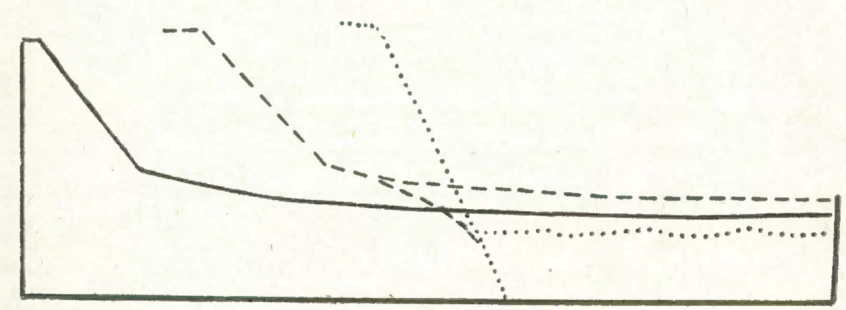


Fig. 5. Stades d'évolution du profil en long de pediments dans les régions à drainage exoréique.

En pointillé : Profil initial. *En tireté :* Développement d'un profil convexe au début de cycle. *En trait plein :* Concavité réalisée à la suite d'un abaissement progressif du profil.

Si enfin le drainage aboutit à un bassin fermé mais dont le niveau baisse, le glacis rocheux affleure à nu et son profil est également concave.

*
* *

Il est généralement admis que pediment de Mc Gee et *suballuvial bench* de A. C. Lawson sont deux termes qui désignent une seule forme [1]. Toutefois il se trouve des auteurs, notamment A. D. Howard [2], qui préfèrent restreindre le *suballuvial bench* aux régions de niveau de base ascendant, là où le glacis rocheux peut être enseveli sous une importante couverture d'alluvions et enfin, là où son profil est essentiellement convexe. Le terme pediment, toujours de l'avis de A. D. Howard, désignerait une surface rocheuse à nu ou recouverte d'une mince pellicule d'alluvions; c'est une surface de transport ou d'évacuation de matériaux sur laquelle il n'y a ni dégradation verticale très marquée, ni dépôt excessif. Le profil longitudinal est normalement concave et peut être formé dans les régions à niveau de base ascendant, sensiblement fixe ou descendant.

V. STADES D'ÉVOLUTION

Si au stade initial du cycle la *bahada* peut envahir les zones déprimées et même les pentes inférieures des montagnes, les pediments se développent et gagnent en surface au fur et à mesure que le cycle d'érosion progresse.

Le début du cycle est marqué par une accumulation de dépôts sous forme de cônes et de glacis alluviaux. Mais cette évolution vers l'ennoyage désertique sous cette couverture alluviale trouve son terme dans l'abaissement du relief montagneux et la diminution de la charge alluviale en masse et en calibre. Les nappes de ruissellement deviennent alors capables de dégrader leurs anciens dépôts.

Lorsque le cycle d'érosion est encore jeune le profil du plancher rocheux peut prendre la forme convexe de A. C. Lawson. Toutefois il est difficile d'admettre qu'un tel profil se maintiendra longtemps. La théorie de A. C. Lawson implique, nous l'avons vu, une diminution

[1] W. M. Davis avait proposé le terme *rockfloor*.

[2] Howard (A. D.), *Pediment Passes and the Pediment Problem., Journ. of Geomorphology*, 1942, p. 3-31, 95-136.

de la hauteur du front de la montagne qui recule parallèlement à lui-même et à vitesse constante. Un versant dont la hauteur décroît fournira nécessairement des apports dont le volume diminuera. Il arrive donc un moment où le front montagneux donnera une charge inférieure à la capacité de transport des nappes de ruissellement (*sheetflood*). Une partie de l'énergie servant au transport de matériaux se trouve ainsi libérée pour accomplir une certaine action érosive sur la surface de pediments dont le profil doit devenir inévitablement concave.

Toutefois W. M. Davis [1] constate que le profil des montagnes granitiques devient convexe dans les stades tardifs. C'est ainsi qu'il considère que les dômes granitiques très surbaissés du désert Mohave (ou Mojave) présentent un relief d'aplanissement aride d'un cycle très avancé sinon final [2].

Donc à mesure qu'un pediment s'étend vers l'intérieur son profil en long doit subir un abaissement progressif [3]. Dans les roches résistantes cet abaissement de profil en long s'explique par le «*floor robbing*» c'est-à-dire l'ablation de la zone superficielle ameublie par la désagrégation chimique ou par les actions météoriques. Dans les roches tendres le processus de corrosion prend plus d'importance que dans les roches résistantes.

Les pediments se développent progressivement aux dépens de la *bahada* d'une part et aussi de la montagne dont le bord reculera sous une pente sensiblement constante. L'élargissement des pediments continuant doit aboutir à la disparition de la montagne et même des *bahadas* formées très tôt au début du cycle. La surface entière est rabotée.

E. Blackwelder [4] constate que les pediments et non les *bahadas* constituent les formes normales et inévitables, développées dans les régions arides sous conditions d'une certaine stabilité du niveau de base.

[1] Davis (W. M.), *Sheetfloods and Streamfloods, op. cit.*, v. p. 1.413.

[2] Davis (W. M.), *Granite Domes of the Mohave Desert* (California), *San Diego Society of Natural History, Transactions VII*, 1933, p. 211-257.

[3] Lefebvre (M. A.), *Note sur les Pediments du désert Mojave* (Californie), *op. cit.*

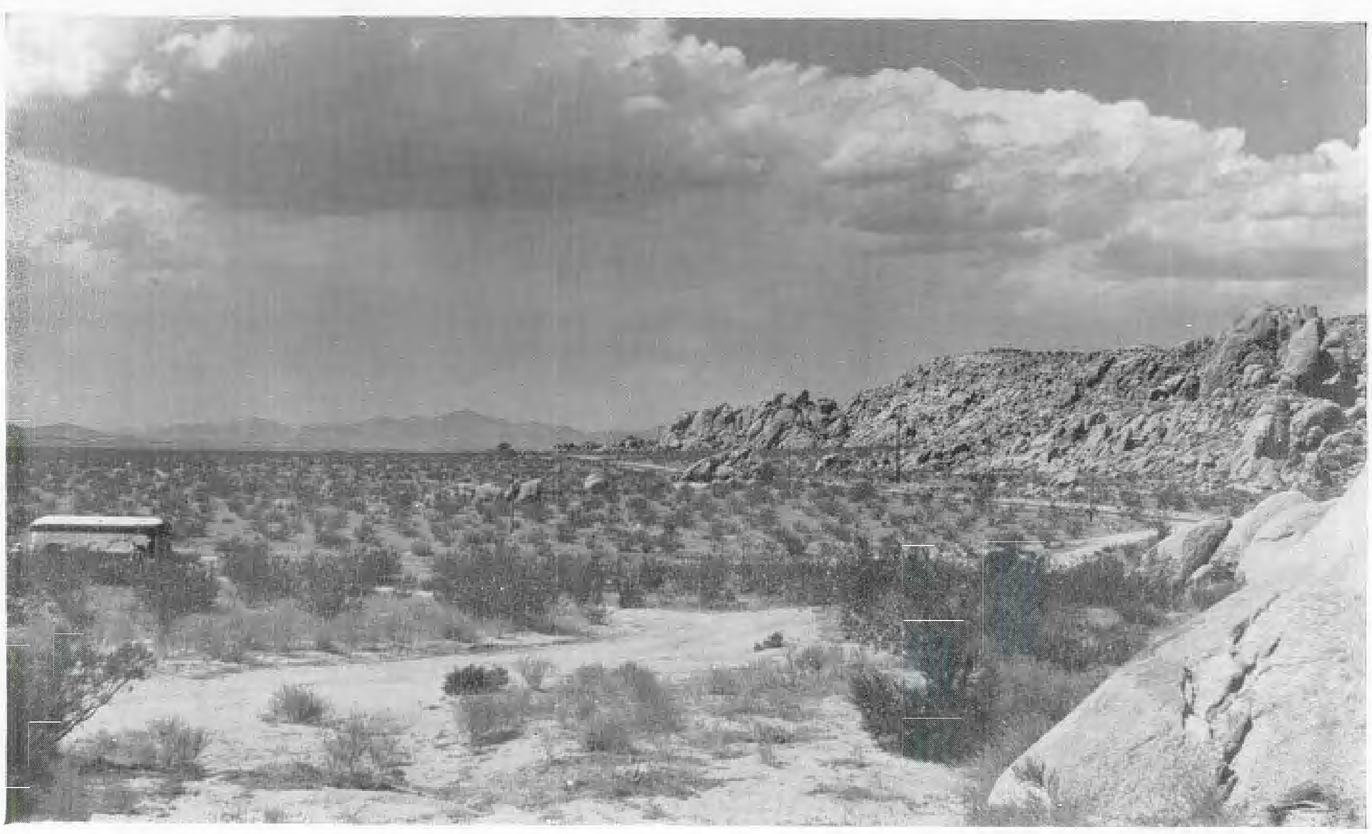
[4] Blackwelder (E.), *Desert Plains, Journ. of Geology*, XXXIX, 1931, p. 133-140.

Cliché Hassan Awad.

Photo du Gebel et du bassin d'Oum-Alaoui (Sinaï). Abrupt tectonique donnant un glacis nivelé par cailloutis, avec buttes résiduelles alignées parallèlement à la faille.

Cliché Hassân Awad.

Large glacis, rocheux que surmontent des chicots isolés. Au premier plan gros blocs de granite en train de se désagréger. (Bassin de Lucerne, Désert Mohave aux Etats-Unis).



Cliché Hassân 'Awad

Pediment sur du granite couvert d'une mince couche d'arène. Le *knick* est bien marqué.
(Bassin de Lucerne Désert Mohave aux Etats-Unis).

Cliché Hassân Awad.

Au-dessus de la surface plane du pediment se dressent des buttes granitiques de faible altitude mais dont le *knick* est néanmoins bien accentué. (Bassin de Lucerne, Désert Mohave aux Etats-Unis).

REMARKS ON THE ORIGIN OF THE EGYPTIAN OASIS-DEPRESSION

BY

G. KNETSCH AND M. YALLOUZE

Lately, Prof. M. Pfannenstiel of Freiburg (Germany) has published a study concerning « Das Quartär der Levante. II. Die Entstehung der ägyptischen Oasen Depressionen», *Ak. Wiss. u. Lit., Math.-Nat. Kl.,* Nr. 7. Mainz 1953 (« The Quaternary of the Levante, II. The origin of the Egyptian Oasis depressions»).

The Work appeared at the same time, when the present authors completed their « Linear structures in the Nile basin» (see reference List). Since the last-named authors came—on a side line of their investigations—to some conclusions concerning the same problem, since, furthermore, the study of Prof. Pfannenstiel deserves a broader interest, the results of a comparative study shall be summarized below. This resumée will be followed by a short statement of the present authors opinion.

Pfannenstiel reviews in detail and critically the opinions offered so-far concerning the origin of these depressions. According to this author neither an explanation by tectonic subsidence nor by wind erosion nor by aquatic scouring can satisfy entirely. He supposes a rather complex evolution in which the cuesta landscape formation (Schichtstufenlandschaft) plays an important role. The depth of the depressions depends on the position of the subterraneous water level (compare Murray 1949, Mayer Yallouze 1954 a. o.). Pfannenstiel gives a painstaking review of depression data : Giarabub, Al Aamara, Melfa, Shebat, Exabia, Gagub, Keiba (all of them about minus 20 m.), Siwa, Maasir and Maraqi etc. (about minus 17 m., with an average level difference between the scraprim and the deepest portion of about 80-90 m.), Kattara, Moghara and

smaller depressions in the neighbourhood (together about 290 km. long and 140 km. wide, deepest known point minus 134 m., average depth by minus 80 m., Southern rim plus 124 m., greatest visible level difference 389 m.), El Areg (minus 25 m., plus 109 m.), Watija (minus 15 m.), Bahrein group (minus 15 m.), Sitra group (minus 33 m. Northern rim plus 85 m.), Fayum (minus 53, plus 340 m.), Wadi Rayan etc. (minus 43, plus 340 m.), Baharyia (average depth plus 130 m. escarpment plus 360 m.), Farafra (plus 26, plus 339 m.), Ain Dalla etc. (plus 88 m., plus 300 m.), Abu Munghar (plus 70, plus 200 m.), Dakhla (plus 70 m., plus 467 m.), Kharga (plus 38 m. plus 300 m.), Dunkul (plus 200 m., plus 318 m.), etc. etc. Pfannenstiel mentions some of the central Saharan oasis depressions also (Marada, Zella, Uau El Khebir).

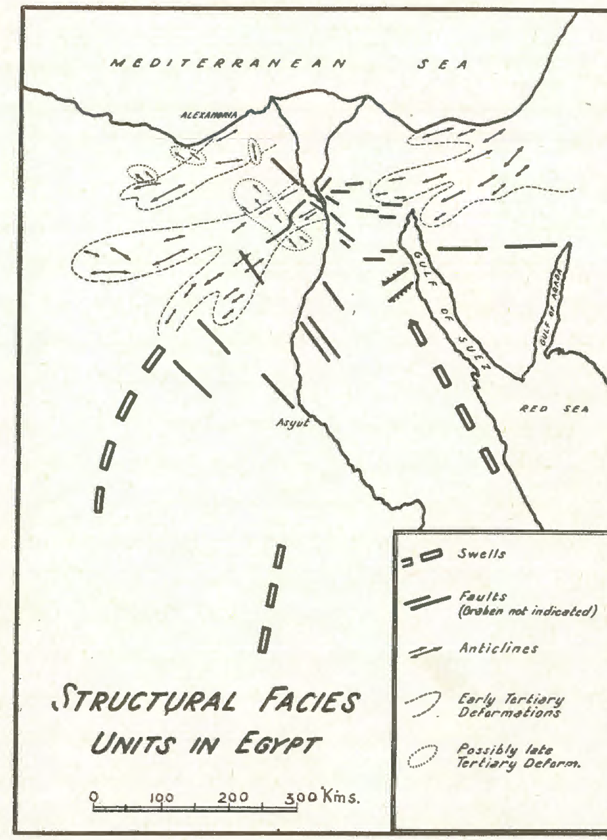
Prof. Pfannenstiel states that nearly all of the depressions are situated immediately upon or next to important geological boundaries (formation-boundaries). The present authors would like to complete or modify this observation by the hint that some of the depressions as well as the most conspicuous escarpements or cuestas of Southern Egypt are situated next to a *facial* boundary, i. e. along a zone where limestone-marl-formations change into coast-near clastic beds of the same age. The Eocene shows transitions into a « Nubian » facies towards the South in the vicinity of Aswan, where Upper cretaceous sandstones with plant leaves indicate a similar attitude of the Upper Cretaceous also. Every type of erosion and denudation will prefer such regions of inhomogeneity.

Pfannenstiel puts some weight on these cuestas as mentioned above. Their formation depends (besides on other factors) on the general dip of the Strata. Steeper dipping units show a narrow spacing of steps, while nearly horizontal sequences display a wide arrangements of cuestas. Beadnell (1903) points out similar facts.

The diminuation of depression-depth from North towards-South depends, according to Pfannenstiel on facies differences of the formations concerned also. The present authors are of the opinion that this change might play a less important role than the level of the subterraneous water level and the thickness of the capillary zone (or fringe) of its leakage « halos ». Nearly all of the authors connected with the general problem agree that most oasis depressions are somehow localized

by tectonic events or tectonic features. The idea is that, tectonic deformation connected with fractures open an easier way for exogene scouring and deepening.

Such tectonic lines have been described rather early. They comprise the Syrian arcs in the Northern portion of the country (Krenkel 1924)



STRUCTURAL FACIES UNITS IN EGYPT

and their swell-continuation towards the Southern region (Mayer Yallouze 1954, Knetsch 1954, Shukri 1954 a. o.). Knetsch regards their transition from actual, confined and local dome-zones of germanotype (at the utmost Jura-type) character, as seen in Northern Sinai, Abu Rawash etc. into the Southern Baharyia swell as a change in structural facies connected with a change in the general character of the region (mobile shelf-stable shelf). That means that « germanotype folding » in

the sense of Stille takes place in mobile shelf areas or para-geosynclines, while swell—and basin—formations are stable shelf or cratonic reactions upon the same tectonic development, which produced the former features.

Swells seem to prefer (as great fractures and grabens do) a diagonal NW and NE-)arrangement either or a normal direction with respect to an alpine folding belt, while the saxonic (or germanotype) style curves readily into the axial trend of the geosyncline and orogen proper. This would give an explanation of the sigmoidal curving of the Northern germanotype sector which has been regarded rather early in literature as the Southern-most, faint waves of the alpine belt.

Pfannenstiel tries (as others have done) to find the southern continuation of the Northern dome-strings of the Syrian arcs. Shukri offers (1954) a similar scheme.

Pfannenstiel anticipates that the Abu Rawash unit begins in the Abu Mungar area in the South and touches Farafra, Ain Sheikh Murzuk, Ain El Wadi, Ein El Makfi, Baharyia, two more depressions North of Baharyia and finally Abu Rawash. The present authors are not sure whether it is possible to follow single tectonic units from one structural facies into another-one. They do, for instance not believe so-far in an arc-like structure in the Qena-Luxor area, nor do they regard Wadi Araba as an anticline of the Syrian arc type. While in the first-named area no actual deformation could so-far be proved (even from the air no indication of that sort could be seen), the Wadi Araba definitely displays a «horst» like feature with huge boundary faults below the Galala-plateaus in the North and in the South of the Wadi (Knetsch 1954).

It might somehow be connected with the evolution of the Syrian arcs but it displays a different structural facies and might just as well be connected mechanically with the origin of the Gulf of Suez (Red Sea) and the later-stage-cross-faulting and splitting of the Sinai-triangle with its (sometimes basalt-filled) E-W-fractures (approximately in the middle between Mt. Musa in the South and the Mediterranean shoreline in the North). A text-figure in this study tries to schematize the present state of knowledge concerning the structures of the Western desert. It is mainly based upon the papers of Shata (1953) and Shukri (1954).

In spite of such differences of opinion a tectonic localization of depressions seems generally accepted. The special type of structures may be of secondary importance.

The excavation of depressions must have taken place by several means and in a rather complex and complicated way. Probably fluviatile erosion prepared some of the depressions in their initial stage. The main factor was—in the opinion of the present writers—exsudation, i. e. chemical action of water, highly enriched in salts by an arid climate. Besides exsudation, i. e. capillary migration of sap etc. and capillary fringes of subterranean waters, sebkha-formation, salt-pans of the normal arid cycle may have played their part also (compare Mayer Yallouze 1954, Knetsch and Refaai 1955, Mortensen 1933 a. o.) Pfannenstiel suspects independently this possibility also. This author assumes a «gliding» of the depression along the dipping strata (either N or NE in most of the Southern depressions). He agrees to the depth limit put by the subterraneous water level.

This water level depends on two main factors :

1) the amount of water and its recharge, that means a climatic dependence, and

2) on the sea level covering its Northern outlet.

1) has been assumed by Ball to depend mainly on regions in the South. This assumption however is narrowed-in by the fact that there is no permeable hydrological connection across the Uweinat-Tibesti-swell. Some authors believe that the water in question is fossil, i. e. a remainder of pluvial rains. 2, concerning the submarine outlet of the «Nubian» water, touches the question of sea level oscillations especially during quaternary times. Their high importance has been pointed out several times by Pfannenstiel (1944, 1950, 1951, 1952, 1953). On the basis of his studies elsewhere in the Mediterranean region he presumes a Mindel-glacial sealevel of approx. minus 200 m., during Würm still minus 90 m., in Riss-Würm-interglacial plus 15 m.., after a preceding intermezzo of plus 35 m. (more figures below). The question is if, and how fast the subterraneous water level reacted upon such release or

increase of outlet pressure and sometimes increased lateral leakage (Nile valley).

In this connection it may be mentioned that recent investigations in connection with the Sadd Al Ali scheme (Aswan) (which have been astonishingly confirmed by nearly analogous South-American stream bed studies) indicate an overdeepening of the Nile valley in this vicinity down to a level of more than 120 m. below present sea level. That would indicate a sealevel of at least minus 250 m. below present sea level during that particular time.

Pfannenstiel tries to narrow-in the age of the depressions and comes to the conclusion that the Southern depressions are older than the Northern-ones. The author tries to fix the age to the initial cuestas at the regression times of the sea covering Egypt. He anticipates that the first escarpments were formed simultaneously with the unconformaties found between Upper-Cretaceous (partly intra-Upper Cretaceous) and Eocene strata. Since, according to the important statement of Shukri (1954), such unconformities are confined to the strings of Syrian arcs (and their Southern representative), the depressions on the other hand are situated along the same zones, Pfannenstiels conclusions are probably right. The author pictures a slight cuesta formation during regression and a burial of the steps after a new inundation and finally a new unearthing of the buried morphology, revival and extension. That means the beginning of depression formation in the South sometime in between Cretaceous and Eocene. The author leaves open, by what forces the cuestas were formed, but this question seems rather unimportant since an « initial plain » will be attacked by any means and result in cuestas first. The climate in Eocene, probably down to at least the lower portion of Miocene was probably humid in our regions. Further North Pfannenstiel suspects the beginning of depression (or cuesta-) formation in the lower Oligocene (Blanckenhorns « Ur-Nil »), in a period of widespread fluviatile reshifting of loose surface material. In Baharyia oligocene sediments are supposed to rest within the depression, although on small tablemountains. A question appears, whether these sediments are actually Oligocene. The coarse clastic facies of Middle Tertiary extents at least into Miocene.

Apparently the type of deformation plays an important role also. No steep dome seems to be converted into a depression. The whole development of Abu Rawash area (Omara 1953, Jux 1954), shows this equally well as the Sinai domes do.

Further remarks on this question will be made at the end of this study.

River action might have created initial stages of depression in the South, the present authors suspected the same development in the Fayum (Mayer-Yallouze 1954). Pfannenstiel presumes the initial stages for the Fayum and Baharyia for the Eocene-Oligocene-boundary.

We assume the first (river-) stages for the Fayum in Miocene, after the fracture period and subsidence of the delta. Ball suspected a South-Western tributary of the Nile carving out the first lines of Dakhla and Kharga oases. He is probably right. His river seems to have followed the main facies boundary between limestone-marl-Eocene and clastic Eocene (as mentione above).

Pfannenstiel furthermore discussed intimately the field of Nile river terraces and old Nile courses. This consideration however is in the whole regarded as comparatively difficult, even fruitless, at the present state of knowledge by the author. Main difficulty seems the unknown degree of overdeepening of the River bed and the time it happened. We know that this deep incision has been filled in again, we do not know, when this happened but apparently it has been done properly with a fill of at least locally low permeability and considerable strength. It should contain a perfect record for « dating the past »; at least the material recovered from the bore holes within the river bed South of Aswan seem to show comparatively fine sediments interbedded with coarse witnesses of pluvial times.

This fjord-like drain should be known to its full extent and age before we try to parallelize events in the Mediterranean, along the Nile and in the Western desert.

This concerns especially the key-like use of the Sandford-Arkell terraces (1928, 1929, 1931, 1934). Pfannenstiel tries to synchronize such terraces and data given by Huzzayin (1941). In this connection we repeat some of the Pfannenstiel statements reproduced above and complete them :

The mediterranean sea level was situated :

During Mindel-Riss-Interglacial or during Riss 1/Riss 2 at about plus 30-35 m. (Tyrrhenien). There is no corresponding beach known in the vicinity of the present delta. A comparison with Sandford-Arkells Pt and PP4, in the Fayum plus 51-45 m. and plus 83, or a paralleliz-ation with the Milazzien beach at plus 60 m. (Mediterranean) seems not quite safe. Still, the relative sequence in there. The Riss/Würm-Interglacial the Mediterranean developped the plus 15 m. beach (Monastirien). During this time the Nile invaded the Fayum basin (plus 34.2 lake-beach).

In Würm the sea level was about minus 90 m. (which means a submarine Nile). In Post-Würm, during the Flandric transgression the sea level rose to approximately plus 5 and plus 7 m. The Nile again entered the Fayum basin.

Consequently, the sea level fell to its present niveau.

As mentioned above, we have no safe chance at present for a parallelizing or synchronizing Nile terraces, depression formation, subterraneous water level fluctuations and the like with eustatic oscillations of sea or ocean levels.

Pfannenstiels relative chronology seems safe, still it remains a relative chronology, which can be built-in in an absolute scheme as soon as some still missing key-details have been discovered.

The Fayum depression came into existence—according to Prof. Pfannenstiel—sometime in-between Oligocene and Würm, with definite deepening stages during Quaternary times.

The question raised by Pfannenstiel, why and how the depressions of Wadi Natrun and Wadi Faregha could be scoured out of clastic sediments has been discussed by Sandford and Arkell also. All three of the authors in question assume a weaker and finer grained facies of the clastics within the depression area. The sediments belong, according to Pfannenstiel (1953) and Zeuner (1950) to the Günz-Mindel-Interglacial, which would mean an excavation of these depressions in Post-Mindel times.

Summarizing Prof. Pfannenstiels time table might be undertaken as follows :

Initial cuesta formation in Southern Egypt in uppermost Cretaceous, resp. at the same time, when the local unconformities of this age developed. This led to the beginning of depression-formation in Kharga, Dakhla, Kurkur, Dunkul.—

Oligocene seems to be the latest-date for the (possibly unearthed and renewed) cuestas near Baharyia, even in Wadi Rayan and Fayum.

In Miocene the Nile confines itself to its present course.

Pont : Scouring of Nile bed to unknown depth with local caving-in and slumping of Nile-escarpments. Consequently epirogene sinking of the whole country with drowing of the Nile bed. Return to the old level in Upper-Pliocene, renewed denudation (plus erosion in the wadis and Nile). Begin of formation of the Northern depressions, Kattara, Siwa, Giarabub, etc.

Early quaternary times : Lifting of country, further denudation and erosion (with partial removal of Nile-bed-fill).

Growing aridity of climate. Nile looses tributaries. No proper depression as yet in Fayum and Wadi Rayan. Begin of excavation of Wadi Natrun and Wadi Faregha.

Middle Quaternary : Pt-gravels in Rus Channel either in Turrhenien I = Mindel-Riss-Interglacial or in Riss 1/Riss 2. By this time deepening of Fayum. Main excavation process in the Fayum during Riss-times (= inter-Tyrrhenien regression).

Tyrrhenien II = filling of Fayum depression and portion of Wadi Rayan.

Würm-glacial sea level = minus 90 m. causes new incision of Nile bed, separation of Nile from Fayum, drying up of Birket Qarun with consequent subaerien deepening. The second ingression of the Nile into the Fayum took place in postglacial times only.

The present authors summarize their opinion on oasis depression formation as follows :

A time table of events appears still too difficult. We aggree with the assumption that the oasis-depression formation took place along structural lines, which represent different reactions upon uniform subcrustal evolutions. Mainly two tectonic facies can be observed : Swells and

basins in the Southern portion of the country (in the extreme and leading over to fractures and graben formation). Their general strike is NE and NW, i. e. they belong to the global «diagonal» lineaments (Stille) of the earth.

The second tectonic facies represented in Egypt shows a germanotype (or saxonic) deformation (Stille 1924-1944). This concerns the aggregate of domes, anticlines, noses etc. of the Syrian arcs (Krenkel 1924. Knetsch 1954, Shukri 1954). These arcs are more or less confined to regions with a thick sediment blanket (mobile shelf with transitions into parageosynclinal regions of the Tethys). Here the deformation met with different types of strata, mobile and competent beds under a slight cover only. These different beds reacted differently within the same structural unit. Mobile material migrated, formed diapirs and was locally squeezed out. The collapsed Abu Rawash unit serves as good exemple. The whole development of different structures of these two fields ends with a time of basaltic intrusions and effusions.

The oasis depressions seem to prefer broad deformations, especially the swell region in the South and broad flexures in the North. We actually do not know a single oasis depression next to a germanotype dome or anticline. Such domes show splendid cuesta formations also, but the depth-development is missing. We suspect that the Northern depressions, Giarabub, Kattara etc. are situated on a third phenomenon of greater tectonics, namely the continental marginal flexure, which seems to form (to some extent) the Cyrenaica (which in itself is a separate climatic region and lies outside the arid field necessary for depression formation).

This dependence on bending plus fracturing elements without migrating ductile (and impermeable) beds seems to indicate that the second important factor of depression formations is water, especially leakage water from deeper horizonts.

Lately, it has been tried (Knetsch and Eglal Refai 1955) to point out anew the importance of chemical action in desert morphology. We believe that the disintegration of rock material took place by means of salt water, which in the case of the Oasis depression leaked out from deeper (Nubian) horizons along fractures connected with swell formation. The

resulting «fines» (everything is being turned into fines in such sebkhas and salt pans but quartz and quartzites) have been exported by the wind. Actual mechanical scouring by sand blast plays a negligeable role in the process of excavation. The excavation level follows the subterraneous water level or its capillary fringe (or halo in case of local leakage.) The water level depends on the two main factors mentioned above, recharge and outlet-pressure.

A third main factor is the aridity which provides even slightly mineralized waters with a high salt content by a high evaporation figure. Murray (1949) has pointed out, to our mind rightly, that in general Egypt was governed by desert conditions since the end of Pliocene times. We think even since early Miocene times. There were a few humid spells in between but none of them was so wet that perennial or even periodic rivers could develop in the Western desert. Strong erosional effects are visible only in areas with a higher hinterland and a comparatively steep gradient (Wadi Hof, Wadi Qena and others, besides a number of short, steep wadis next to the coast between Mersa Matruh and Bardia. Their mouths are drowned, they have possibly be formed during a very low sea level in quaternary times).

The deepening of the depressions came to a standstill, when the water level rose after times of eustatic positiv sea level movements. Kattara depression is most probably drowned. Wadi Natrun is not only fed by subterraneous Nile water entering from the Nile valley but is also being invaded by dunes.

In the whole there are still a number of open questions. It can safely be assumed that the evolution sketched above formed some of the depressions. The excavation of others must have taken place in another way but along similar conditions.

REFERENCES

Ball, J., Kharga Oasis, *Surv. Dep.,* P. W. Min., Cairo 1900.

—— On the topogr. and geol. results of a reconnaissance survey of Jebel Garra and the Oasis of Kurkur. Cairo 1902.

—— Contributions to the Geogr. of Egypt., *Surv. Dep.,* Cairo 1939.

—— and H. J. L. Beadnell, Bahariya Oasis, *Surv. Dep. PWM.,* Cairo 1903.

BEADNELL, H. J. L., Dakhla Oasis, *Surv. Dep. PWM,* Cairo 1901.
—— Flowing wells and subsurface water in Kharga oasis, *Geol. Mag.,* London 1908.
—— An Egyptian Oasis (Kharga), etc., *Phys. Geogr. and water Supply,* London 1909.
BLANCKENHORN, M., Aegypten. Hdbch. d. reg. Geologie (9), 7. Heidelberg 1921.
BURNOFF, S. v., Über die Gerüstbildung der Erde. *Naturwiss,* 26, H. 46, 1938.
—— Grundprobleme der Geologie, Halle 1949.
CUVILLIER, J., Revision du Nummulitique Egyptien, *Mem. Inst. d'Eg.* 16, 1930.
HUZZAYIN, S. A., The place of Egypt in Prehistory, *Mem. Inst. d'Egypte,* 43, 1941.
JUX, U., Zur Geologie des Kreidegëbiets von Abu Rawash etc. (with complete references) N. *Jb. Geol. Pal., Abh.* 100, 1954.
KNETSCH, G., Mitteilung über neuere Beobachtungen z. Geol. d. Marmarica, *Geol. Rdsch,* 33, 1942.
—— Strukturelle Skizze von Eegypten, *Geol. Rdsch,* 42, 1954.
—— and Eglal Refai (Cairo), Wüsten morphologie, Chemismus etc., N. Jb, *Geol. Pal.,* Abh. 101, 1955.
KRENKEL, E., Der Syrische Bogen, Zbl. f. Min, etc. 1924.
—— Geologie Afrikas I. Berlin 1925.
—— Die Struktur der Sahararegion, *ZdDGG,* 92, 1940.
LITTLE, O. H., Recent geol. work in the Fayum etc., *Bull. Inst. d'Egypte,* 18, Cairo 1936.
MORTENSEN, H., Die Salzsprengung, etc., *Peterm. Mitt.,* 1933.
—— Neues z. Problem der Schichtstufenlandschaft. *Nachr. Ak. Wiss. Göttingem Math.-Phys. Kl. IIa,* 2, 1953.
OMARA, S. M., The Structural features of the Giza Pyramide area, *Diss.,* Cairo 1953.
PASSARGE, S., Zur Kenntnis des Fayums, *Die Naturwissensch,* 36, 1944.
PFANNENSTIEL, M., Die diluvialen Entwicklungsstadien u. d. Urgeschichte von Dardanellen, Marmarameer und Bosp., *Geol. Rdsch,* 34, 1944.
—— D. Quartärgeschichte des Donaudeltas, *Bonner Geogr. Abh.* 6, 1950.
—— Quartäre Spiegelschwankungen des Mittelmeers u. d. Schwarzen Meers. *Naturf. Ges. Zürich,* 46, 1951.
—— Das Quartär der Levante I, *Ak. Wiss. u. Lit. Math. Nat. Kl.* Mainz. 1952.
—— Zur Quartärgeschichte des Niltals. Geol., *Rdsch,* 40, 1952.
—— Das Quartär der Levante II. Die Entstehung der ägyptischen Oasendepressionen, *Ak. Wiss. u. Lit. Math.Nat. Kl,* Mainz 1953.
SANDFORD, K. S., and W. J. ARKELL, The relations of Nile and Fayum in Pliocene and Pleistocene times, *Nature,* London 121, 1928.
—— The origin of the Fayum depression, Geogr. J. London 74, 1929.
—— Paleolithic man and the Nile-Fayum-divide, *Orient. Inst. Publ. Univ. of Chicago,* III, 10, 1929.

SANDFORD, Paleolithic man and the Nile valley in Upper Egypt, etc. *Orient. Inst. Publ.* Chicago 18, 1934.
—— Paleolithic man and the Nile valley in *Lower Egypt O. I. Publ.* Chicago 46, 1931.
SHATA, A. A., An account of the geology of N. Heneinat area etc. *Bull. Inst. Desert.* I, Cairo 1953.
SHUKRI, N. M., Remarks on the geological structure of Egypt, *Bull. Soc. Geogr. d'Egypte,* 27, 1954.
STILLE, H., Grundfragen der vergleichenden Tektonik. Berlin 1924.
—— Geotektonische Gliederung der Erdgeschichte, *Abh. Pr. Ak. Wiss. Math-Nat. Kl.* 3, Bln. 1944.
TROMP, S. W., The age and origin of the Red Sea graben, *Geol. Mag,* 87, 1950.
—— Preliminary compilation of the macro-stratigraphy of Egypt, *Bull. Soc. R. Géogr. d'Egypte,* 24, 1951.
YALLOUZE M. and G. KNETSCH, Linear structures in and around the Nile Basin, *Bull. Soc. Géogr. d'Egypte,* t. XXVII, 1954.
ZEUNER, E. F., Dating the Past, 2nd ed. London, 1950.

THE PRE-CAMBRIAN HISTORY

OF THE GULF OF SUEZ AREA

BY

H. M. E. SCHÜRMANN

In January it was exactly 40 years ago that I became acquainted with the basement of Egypt. My latest summary, with map, was given at the International Geological Congress in Algiers in 1952.

The youngest Pre-Cambrian is probably 600 million years old and

Fig. I. Mitiq series (blocks) and Atalla series (lines) folded and intruded by Shaitian granite (vertical crosses). Latter eraded to denudation-line A-B.

the oldest (the deepest part of the earth's crust) probably exceeds 2.000 million years. These figures show that the Cambrian and post-Cambrian periods together lasted less than half as long as the Pre-Cambrian. In view of the number of Plutonic periods during the last 600 million years, one can analogically expect double the number of orogeneses with greater granite-intrusions in the Pre-Cambrian with its more than 1200 million years.

The attached table gives a survey of the Pre-Cambrian of Egypt. With regard to the Gulf of Suez area it should be stated that the older Pre-Cambrian rocks are rare here. They are more numerous in the southern part of the Eastern Desert and, except in the Sinai, appear less often to the North.

On five schematic profiles I have tried to sketch the historical development of the Younger Pre-Cambrian of the Gulf of Suez area. I have

started with the big orogenesis which took place after deposition of the Metarchaean and which was connected with large granite-intrusions, the so-called Shaitian.

Figure I shows the Mitiq and Atalla series more or less strongly folded and intruded by the Shaitian granite. After this folding and intrusion, a regional erosion took place and on top of this erosion-surface the old paraschists were deposited (Hume). After this deposition a weak folding took place, manifesting itself clearly in the old paraschists and accentuating the earlier folding in the older layers.

Figure II shows the weakly folded series of the old paraschists. After deposition of these series, a fault-tectonic phase took place and, in the troughs, the younger Eparchaean—the Shadli (predominantly sediments) and the somewhat younger Dokhan series (predominantly volcanic rocks)—was deposited, but only where no pronounced geological highs were present. Figure III illustrates this situation.

After the deposition of the Dokhan series a new folding occurred, after this erosion took place and finally the surface became more or less a peneplain. After that fault-formation again took place and in the troughs formed in this manner the youngest Pre-Cambrian i. e. the Hammamat series were deposited (Figure IV). After deposition of these Hammamat series, which are generally very little folded, big granite-intrusions at relatively small depth took place, the so-called Gattarian; strong erosion (Figure V) followed, peneplaining the Pre-Cambrian and during the subsequent transgression the Cambrian and post-Cambrian sediments were deposited.

Along the Gulf of Suez the oldest post Pre-Cambrian rocks left are not the Cambrian, as in Jordania, but the Carboniferous or possibly Devonian.

In the younger Pre-Cambrian two great periods of Plutonic intrusions can thus be distinguished viz. the Shaitian and the Gattarian which are tectonically practically uninfluenced. Furthermore, one or even more older granite-intrusions took place, which should be considered to be of Protarchaean origin and which are tectonically strongly influenced (Orthogneiss)

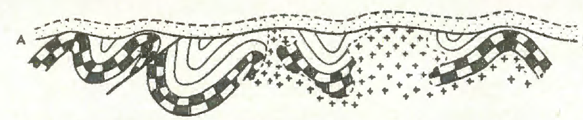


FIG. II. Deposition of Old Paraschists (small dots). Unconformity (A-B) and Old Paraschists gently folded.

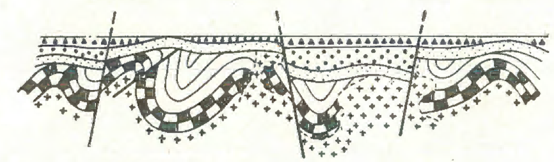


FIG. III. Faulting. In the troughs thick sediments and on highs reduced sediments of Shadli series (marine; big dots) and Dokhan series (volcanic; triangles). On topographic highs sometimes not deposited.

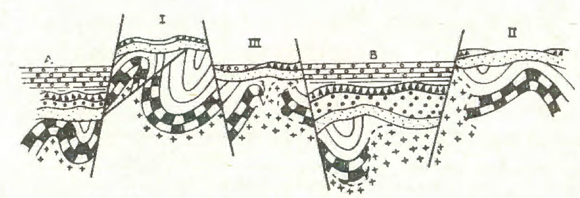


FIG. IV. Folding and faulting. In troughs, A and B, deposition of mainly continental beds of Hammamat series (circles). On horsts (higher blocks, I and II) Hammamat not deposited or just rudimentary (block III). New erosion cycle.

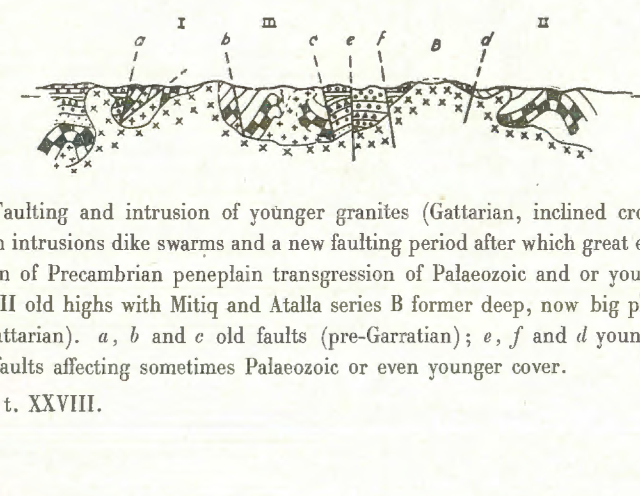


FIG. V. Faulting and intrusion of younger granites (Gattarian, inclined crosses). After Gattarian intrusions dike swarms and a new faulting period after which great erosion. After formation of Precambrian peneplain transgression of Palaeozoic and or younger beds.

I, II and III old highs with Mitiq and Atalla series B former deep, now big plutonic intrusion (Gattarian). *a*, *b* and *c* old faults (pre-Garratian); *e*, *f* and *d* young (post Gattarian) faults affecting sometimes Palaeozoic or even younger cover.

The three main unconformities of the Eparchaean are :

1) The old paraschist transgression ;

2) The Shadli-Dokhan transgression ;

3) The Hammamat transgression ;

For the determinations of age of the main intrusions it is necessary not only to make detailed field-studies, but also to investigate the radioactivity of the minerals isolated from the various Plutonics.

GATTARIAN	Granite of second series and dykes	Mons claudianus granite	Normal igneous ; calc-alkali and alkali magmas (Na) ; no metamorphism ; sometimes marginally gneissic.
	Epeirogenesis Hammamat series	Breccia verde antico	Sandstones, breccias and conglomerates with interbedded quartz-dioritic flows, only locally contact-metamorphic ; no regional metamorphism.
EPARCHAEAN	unconformity Dokhan series.... Shadli series.....	Porfido rosso antico	Quartz-dioritic flows predominant tuff and some sediments. Gabbro and serpentine? schists (red, black and green) some breccias, tuffs, subordinate flows. No regional metamorphism.
	unconformity Series of old paraschists........	Red breccia......	Metamorphic sediments, marbles ; andesitic flows (Barthoux) red aplite-breccia, hälleflintas ; regional metamorphism (Epizone).
SHAITIAN	unconformity Granite of first series.........	Shait granites ...	Normal igneous ; occasionally gneissic ; calc-alkali magma and some alkali magma (Na). No indications of intensive metamorphism.

METARCHAEAN	Atalla series	Steatite	Quartzite, red jasper, rhyolitic flows, hälleflintas ; also some andesitic flows. Baramia Magnesium series (steatite, gabbro and serpentine) quite intensive epi-metamorphism.
	Mitiq series.....	Gneisses........	Highly metamorphic schists (Mesozone) mica-schists, marble, paragneisses (Gebel Bedun) and orthogneisses of calc-alkali magma. (Wadi Ghazala). Upper Feiran orthogneisses and paraschists (Meso-Katazone).
PROTARCHAEAN	Fundamental gneiss..	—	Migmatites of Wadi Feiran (Katazone).

ANCIENT SHORE-LINES OF EGYPT

PART I—THE PALEOZOIC

BY

SAID, R. AND SHUKRI, N. M. [1]

This note is the first of a series of three papers that deal with ancient shore-lines of Egypt during its geologic history. A great deal of information regarding the areal extent of the different systems in Egypt has been collected in recent years through the numerous bores that were drilled by oil companies particularly in the Gulf of Suez area.

Geologically, Egypt, with the exception of its northern part, forms a part of the stable foreland shelf of the basin development whose borderland is represented by the Cyprus-Persian Gulf nappe zone (Weeks, 1952). During its geologic history this shelf has been intermittently covered by the sea and the present paper deals with the ancient shore-lines of the Paleozoic era.

There is evidence to believe that Egypt remained a land mass from the Cambrian up to the early Carboniferous time. Up to the present no surface exposures or subsurface occurrences of Cambrian have been recorded in Egypt even though the Cambrian is known to exist from Iran to N. W. Africa. Whether this distribution indicates the existence of an east-west Tethys as early as the Cambrian is subject to question. Analysis of the Cisjordan Cambrian fauna by Richter and Richter (1941) has shown that these faunas have strong affinities to the Pacific province. This, in their opinion, constituted an indication of the possibility that the Palestinian Cambrian was deposited in an invading sea from the west rather than in an invading «Tethys» from the east. If these conclusions are correct, then we may be confronted with a paleogeography

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[1] Names are alphabetically arranged.

that shows the Eastern Mediterranean basin to be a later development than the Cambrian.

This view is supported by the absence of any marine Cambrian deposits in Cyprus, Greece, Turkey or Lebanon. In Libya, a small exposure of ? Cambrian is recorded in Tibesti (Desio, 1942) which probably belongs to the western Mediterranean geosynclinal zone comprising the Black Mountains, Sardinia and Morocco. The Iran thick Cambrian may belong to the Pacific arm suggested by Richter and Richter.

Hupe (1953) has recently analysed the Lower Cambrian trilobite fauna of Morocco and has found out that although most of the fauna belonged to the Atlantic province, there were some from the Pacific. This would mean that some sort of connection must have been in effect between N. W. Africa and the Pacific. The same connection has also been assumed to have existed in the Devonian by Gill (1953). This was based on a comparative study of the Australasian and European faunas. Whether this connection was through the « Tethys» or through some other seaway needs further investigation.

No work has been done on the faunas of the Ordivician recorded at Tebulk, Syria, nor on the Silurian known from inner Arabia, nor on the Devonian recorded from Mudawara on the Hejazo-Jordanian border. However, no exposures of these ages have been recorded within the boundaries of Egypt. Therefore, we assume that Egypt, during that part of early Paleozoic time, must have belonged to that stable foreland of the Arabo-African shield.

Picard (1953) has recently assigned a Silurian age to the black limestone series in Wadi Meneiah, Palestine that overlies the lower unfossiliferous Nubian Sandstone and which is overlain by the Manganese ore horizons. Picard's age determination was based on the finding of one specimen in the black limestone series referred to the genus *Platystrophia* that characterizes the Middle Ordovician to the Middle Silurian in North America. Fossils that were described previously from this series need, according to Picard, re-examination. Picard compared the Meneiah section with the Um Bogma section in Sinai and suggested that the lower Nubian Sandstone below the Manganese bearing horizon may also be of lower Paleozoic age.

If Picard's age determination is accepted for Wadi Meneiah black limestone, then the Silurian shore-line should extend slightly to the west and south to include this exposure. However, we shall not extend

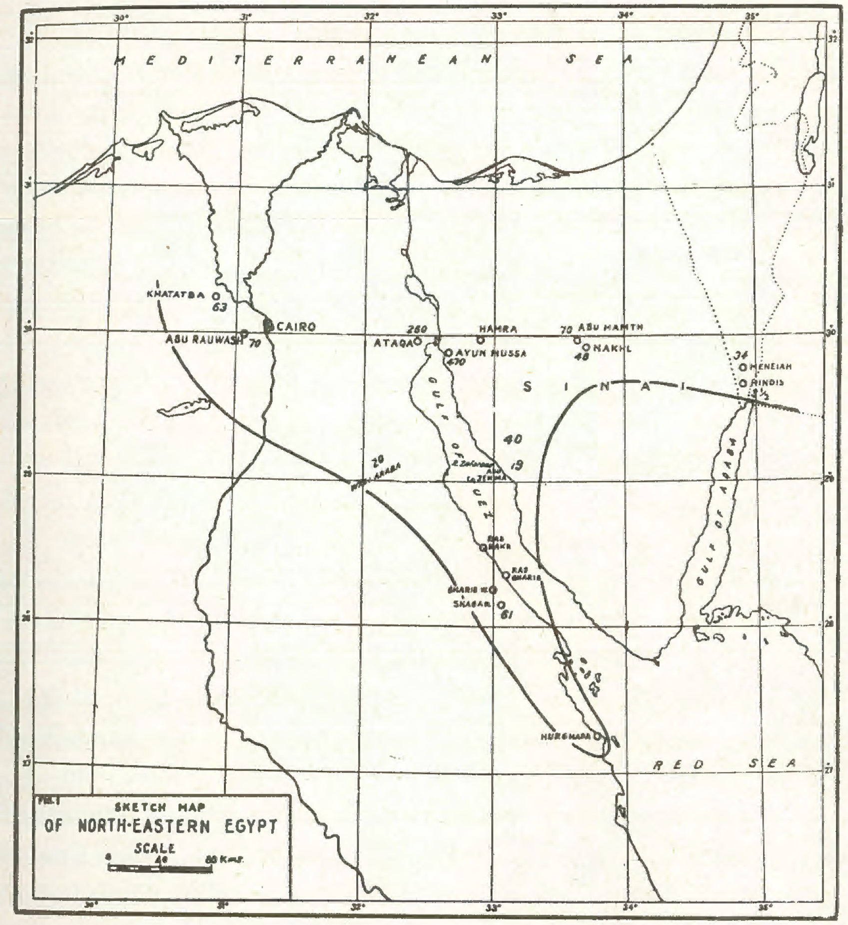

Fig. 1 : Showing Carboniferous ancient shore-line.

this shore-line to Um Bogma in Sinai until authentic Paleozoic fossils are found in the lower Nubian Sandstone of Sinai. The occurrence of this sandstone conformably below the decidedly marine and richly fossiliferous Carboniferous of Sinai with no break in sedimentation or change of dip makes its age, in our opinion, either Carboniferous or at the base of the Carboniferous but most improbably Silurian or earlier. Picard's

analogy between the two sections of Meneiah and Um Bogma on the inference that both lie below the Manganese bearing strata cannot be true since Manganese may occur, as he himself has noted, in different ages. The Manganese horizon in Sinai is decidedly of metasomatic origin and was formed in post-Carboniferous time.

Ploeg (1953, p. 151) reports that samples taken from the Nubian series near the basement of wells drilled at Hurgada and Ayun Mussa yielded plant remains which according to Jongmans, probably belong to the Devonian. Later, Jongmans (1953), changed his opinion about the age of these occurrences to Lower Carboniferous, although he identified the presence of ? terrestrial Devonian in Hurgada.

THE CARBONIFEROUS SHORE-LINE : With the advent of the Carboniferous, the picture changes. There is evidence of a wide spread marine transgression that covered the north-eastern part of Egypt. This is witnessed by the marine exposures of Carboniferous in that part of Egypt.

I. MARINE CARBONIFEROUS OUTCROP OCCURRENCES

On the Sinai side of the Gulf of Suez east of Abu Zeneima a series of marine limestones overlie the sandstone of the unfossiliferous Nubian facies and are overlain by *Lepidodendron* bearing Nubian Sandstone. The thickness of the calcareous fossiliferous part of this section is about 40 m. in Nukhul, about 19 m. in Um Bogma to the south-west, and very thin and almost vanishing at Sarabit el-Khadem and Um Reglein. There is a thinning of the section towards the south-east of Nukhul. The thickness of the lower Carboniferous sandy unfossiliferous facies is 130 m. and that of the upper sandstone part is some 650 m. of which the lower 150 m. are decidedly Carboniferous in age as suggested by associated *Lepidodendron* flora (Ball, 1916).

A similar succession occurs also in Wadi Araba on the opposite side of the Gulf of Suez. The thickness of the calcareous fossiliferous part is less than half that of Um Bogma (Ball, 1916) and is mostly of marly nature denoting nearness to landmass. The lower sandstone series is some 100 m. thick whereas the upper sandstone is about 250 m. thick (Tromp, 1951). The whole section thins towards the west.

II. SUBSURFACE CARBONIFEROUS OCCURRENCES

Several subsurface occurrences of Carboniferous are known from the logs of wells drilled in the north-eastern part of Egypt. In Wadi Meneiah and Gebel Hindis just across the borders of Egypt to the north-east of Aqaba, the thickness of the mainly dolomitic fossiliferous Carboniferous is 34 and 3 ½ m. respectively. The thickness of the lower sandstone series of Meneiah is at least 35 m. while it is 15 ½ m. in Hindis (Ball and Ball, 1953).

At Abu Hamth the Carboniferous is represented by some 730 m. of sandstone of the Nubian facies and fossiliferous limestone series with dolomitic and shaly intercalations. The limestone of this section has a thickness of some 70 m.

At Nekhl the Carboniferous has a thickness of some 280 m. of which the fossiliferous limestone part is 48 m. thick.

At Ayun Mussa slightly to the south of Suez on the Sinai side the Carboniferous attains a thickness of some 650 m. The fossiliferous limestone and dolomitic part of this thickness is 470 m. At Hamra the Carboniferous is at least 260 m. thick while at Ataka it is 380 m. in thickness of which the marine limestone facies is 260 m. thick. At Ras Bakr some 380 m. of Carboniferous sediments occur.

To the south of the western part of the Gulf of Suez at Ras Gharib, the marine Carboniferous is known from the logs of numerous bores in the well known oilfield. Here the Carboniferous marine limestone facies changes into a black shale facies which lies between the sandstone facies. In Ras Gharib 25, for example, the marine Carboniferous shale is 126 m. in thickness, while at West Gharib 3 it is some 47 m., at West Gharib 4 some 82 m. and at Shagar 1, the most southerly occurrence in the area, some 61 m. in thickness.

Reported marine Carboniferous in recent rotary wells drilled at Hurgada is some 100 m. thick.

Only two subsurface occurrences of Carboniferous are reported west of the Nile, namely that at Abu Rawash where the Carboniferous is some

270 m. of which the fossiliferous limestone part is some 70 m. and that at Khatatba, where the Carboniferous is reported to have a total thickness of some 240 m. of which the marine limestone part is 63 m. in thickness.

III. DISCUSSION

The thicknesses of the decidedly fossiliferous marine facies of the known Carboniferous outcrops and subsurface occurrences are given in Fig. 1. It is immediately evident that it is possible to reconstruct out of this data a general isopach map which would show general thinning of the formation towards the ancient shore-line reconstructed in this figure. This shore-line passes slightly south of Gebel Hindis in the east, then to the south-east of Nukhul, turns southwards to include the occurrences of Ras Gharib and Hurgada in the form of a gulf which turns north to pass by the very thin exposure to the west of Zaafarana and south of Cairo. The Abu Rowash Carboniferous occurrence is thicker than the northern occurrence at Khatatba. This may be interpreted, contrary to current ideas, as due to a slight turning of the shore-line to the north-east of Khatatba. This brings the area of Khatatba nearer to the supposed ancient shore.

This Carboniferous shore-line offers many interesting features that are worth emphasizing. The ancient Ras Gharib Carboniferous Gulf occupies to-day almost all the Gulf of Suez, a feature that may indicate the existence of a zone of subsidence in this area as early as the Carboniferous as suggested by Hassân Awad (1951). It may be of interest to note that this Carboniferous bay is bound by shores that have the erythrean trend. This trend is known to occur, among other trends, in the foundation crystalline rocks (pre-Carboniferous) (Shürmann, 1953). It seems, therefore, that the boundaries of this ancient gulf have been formed through a rejuvination of movement along this old erythrean trend (Shukri and Said, in preparation). Shackleton (1954) states that in the south the Erythrean Rifting System follows the Karroo structures, but that in the north, in Egypt, « paleogeographical reconstructions show no evidence of a rift before the Miocene». Shukri (1953) and Shukri and Akmal (1953) have shown that the rifting in Egypt is also of pre-marine Miocene age «Oligocene» thus confirming the work of Barron (1907). This paleogeographical reconstruction of the Carboniferous indicates that the trend is of an even earlier age, thus completing the picture, given by Shackleton for the south.

An interesting feature in the distribution of marine sedimentary facies in the Carboniferous is the presence of black shales in the assumed Ras Gharib Gulf as compared with the open sea calcareous facies in the north. This may be explained by assuming that the black shales were deposited in an enclosed gulf that was separated from the open sea by a sill. This gulf must have received great quantities of fresh water to bring about a Black Sea type of basin where the inflow over the sill would cause an unareated bottom most favorable for the formation of black shales. A north-east south-west sill may have separated this gulf from the open sea. The presence of this sill would not only complete this setup necessary for the development of a basin most suitable for the accumulation of this type of facies, but would also mean the presence of an elevation that ran in alignment with the old Syrian swell system known to be pronounced in the Cretaceous time (Shukri, 1954; Shata, 1954). Thus this system of folds may have roots in the Carboniferous. Actually this trend is clearly foreshadowed in the fundamental rocks of Egypt (Andrew, 1939; Schürmann, 1953; Shukri and Lotfy, 1954).

Our assumption that the ancient Carboniferous shore-line turns towards the east to the north of Khatatba closes this ancient sea and brings Khatatba near to the shore. This offers an explanation of the thinning of the sediments at Khatatba. If this interpretation of the shore-line is correct, then our earlier assumption that the eastern Mediterranean is of late origin is substantiated, for the Carboniferous Sea is still the westward invasion of the great ancient eastern sea rather than an invasion from the north and the west as customarily assumed in treatises of Paleogeography.

IV. CONCLUSIONS

The following are some of the more interesting probable conclusions drawn from this picture we have depicted of the ancient shore-lines :

1. that the erythrean as well as the Syrian tectonic trends are faintly indicated in the paleogeographic reconstruction of the Carboniferous;
2. that the black shale facies of the marine Carboniferous may be explained by assuming its deposition in a non-areated enclosed basin separated by a sill from the northern open sea;
3. that the ancient Carboniferous climate must have been wet;
4. that there is good evidence that a westwardly invading Pacific sea covered parts of Egypt and adjoining countries up to the end of the Carboniferous time.

BIBLIOGRAPHY

Andrew, G., 1939, The Greywackes of the Eastern Desert of Egypt, *Bull. Inst. Egypte,* 21, 153-190.

Awad (Hassân), 1951, La Montagne du Sinaï Central, étude morphologique, Pub. of Geogr. Soc. of Egypt, Cairo.

Ball, J., 1916, The Geography and Geology of West-Central Sinai, *Survey Dept.,* Cairo.

Ball, M. W. and Ball, D., 1953, Oil Prospects of Israel, *Bull. Amer. Assoc. Pet. Geol.,* 37, 1-113.

Barron, T., 1907, The Topography and Geology of the District between Cairo and Suez : *Survey Dept.,* Cairo.

Desio, A., 1942, Übersicht über die Geologie Libyens, *Geol. Rundschau,* 33, 415-421.

Gill, E. D., 1953, Relationships of the Australasian and North African Lower Devonian faunas, *C. R. Congres géol. Internat., 29th session, sec. 2, fas.* 2, pp. 87-92.

Hupe, P., 1953, Sur les affinités des Trilobites du Cambrien inférieur Marocain, *ibid.,* pp. 41-48.

Jongmans, W. J. and Heide, S. van der, 1953, Contribution à l'étude de la faune et de la flore Carbonifère inférieur de l'Egypte, *ibid.,* pp. 65-69.

Picard, L., 1953, Silirian in the Negeb (Israel), *ibid.,* pp. 179-183.

Ploeg, P. van der, 1953, Egypt, in the World's Oilfields, *Science of Petroleum,* vol. IV, pt. 1, 151-157.

Richter, R. and Richter, E., 1941, Das Kambrium am Toten Meer und die alteste Tethys, *Abh. Senckenberg. Naturfer, Gesell.,* No. 460.

Shackleton, R. M., 1954, The Tectonic Control of Igneous Activity, *Inter-University Congress, Univ. Leeds,* pp. 21-23.

Shata, A., 1954, New Light on the Structural Developments of the Western Desert of Egypt, *Bull. Inst. Desert Egypte,* 3, 101-106.

Schürmann, H. M. E., 1953, The Pre-Cambrian of the Gulf of Suez Area, *C. R. Congres geol. Internat,* sec. I, fasc. 1, pp. 115-135.

Shukri, N. M., 1953, The Geology of the Desert East of Cairo, *Bull. Inst. Desert* 3, No. 2, pp. 89-105.

Shukri, N. M., 1954, Remarks on the geological Structure of Egypt, part I; Cretaceous Eocene Relations, *Bull. Soc. geogr. Egypte,* 27, 65-82.

Shukri, N. M. and Akmal, G., 1953, The Geology of Gebel el-Anqabia and Gebel el-Nasuri District, *ibid.,* 26, 243-276.

Shukri, N. M. and Lotfy, M., 1954, The Geology of the North-Western Part of Gebel Siwiqat El-Arsha Area, Eastern Desert of Egypt, *Bull. Fac. Sci.,* 32, 25-46.

Shukri, N. M. and Said, R., *Remarks on the Geological Structure of Egypt;* part II, Tectonic trends (in preparation).

Tromp, S. W., 1951, Preliminary Compilation of the Macro-Stratigraphy of Egypt, *Bull. Soc. Geogr. Egypte,* 24, 55-103.

Weeks, L. G., 1952, Factors of Sedimentary Basin Development, *Bull. Amer. Assoc. Petr. Geol.,* 36, 2071-2124.

CONTRIBUTION TO THE STUDY
OF HELWAN SULPHUR AND MINERAL SPRINGS

BY

M. I. ATTIA

HISTORICAL

Helwan is an ancient town; it is said to have been named after Helwan the king of Fustat.

It was during the reign of Muhammed Aly el-Kebîr (1805-1848) that a map of Helwan was made and the site of the sulphur spring was located.

In 1850, Abbas Hilmy I (1848-1854) has ordered the construction of a small building at the site of the sulphur spring. The building consisted of two rooms in which soldiers of the Egyptian Army—suffering from skin diseases—were treated.

In 1868, during the reign of Khedive Ismail (1863-1879), a scientific committee was appointed to examine the water of the sulphur spring. This committee recognised the various merits of the water and the Ministry of Public Works was asked to construct a building for a bath at the site of the sulphur spring. It was during the excavations for the foundations of this building that another sulphur spring was encountered. The Khedive Ismail—who took a particular interest in these sulphur springs—appointed Dr. Reil as Director of the Helwan Baths in 1872.

In 1896, the Egyptian Government appointed Dr. Page May medical director of the baths. He appreciated the medicinal qualities of the sulphur springs and made the plans of the present sulphur-bath building which was officially opened by the Khedive Abbas Hilmy II in 1899

Up to that time, the Egyptian Government was running the Sulphur

Baths as well as Taufîq Palace Hotel at Helwan; these were —later on— rented to the Egyptian Hotels Company.

In 1925-1926, a Ministry of Public Health Committee was formed with the object of studying the existing sulphur springs and to find out if the waters of these springs vary in their chemical composition. The conclusion arrived at by this committee was that the origin of all the sulphur springs of Helwan is the same and that the chemical composition of the waters—judging by a series of analyses carried out during a whole year—does not vary. A report has been submitted to the Under Secretary of State for the Ministry of Public Health.

In 1938, the Minister of Finance appointed a committee to investigate the condition of Helwan town and the sulphur baths and to suggest means for the development of the town and the baths. This committee consisted of representatives of the Ministry of Public Health, the Ministry of Commerce and Industry, the State Domains Administration, Cairo Tanzîm Department, the State Building Department and a representative of the land owners of Helwan.

The committee studied the causes of the decline of Helwan town; the condition of the sulphur baths; the means of communication from Cairo to Helwan; the condition of Helwan town; the means of recreation and sports; the population of the lands west of Helwan town; the drainage scheme of Helwan town; the formation of a Municipality for Helwan; etc. and made certain proposals.

An Arabic report was submitted by the committee to the Minister of Finance; this report was published by the State Domains Administration in 1939

In December 1948, a Committee was formed under the Presidency of the Minister of Commerce and Industry for the development of Helwan Town.

The Committee consisted of representatives of the various departments concerned from the Ministries of Commerce and Industry, Communication, Education, Finance, Interior, Public Health, Public Works and Social Affairs. Certain proposals were put down and few of them were carried out.

It may be of interest to note that up till the time of writing this note, there have been no additions or important improvements on the building of the sulphur baths of Helwan since its foundation in 1899.

LOCATION OF HELWAN

Helwan El-Hammamat is about 25 km. south-south-east of Cairo. It is situated in the Eastern Desert at the foot of the hills bordering the Nile Valley. The centre of the town is 3.800 km. east of the River Nile

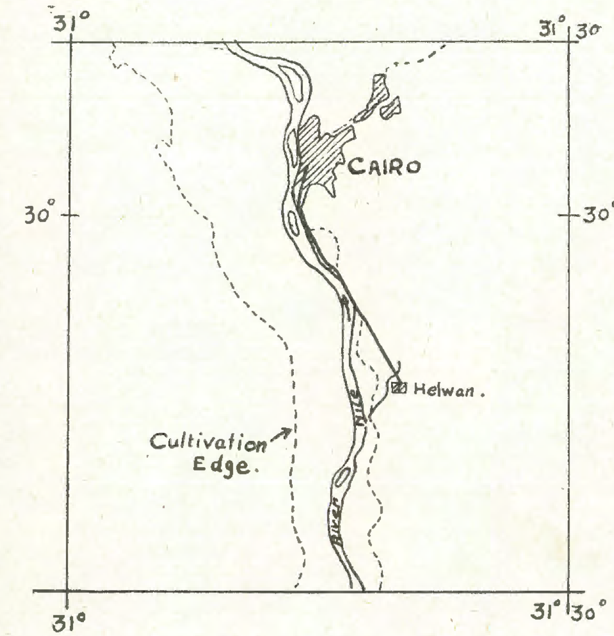

Fig. 1. Sketch-map showing the position of Helwan (Scale 1 : 500.000).

right bank and 2.250 km. east of the cultivation edge. (See sketch map Fig. 1).

The altitude of Helwan town ranges from 45 m. to over 60 m. above mean sea-level; its height, therefore, ranges from 25 m. to over 40 m. above the water level of the River Nile in that vicinity (See contoured map Fig. 2).

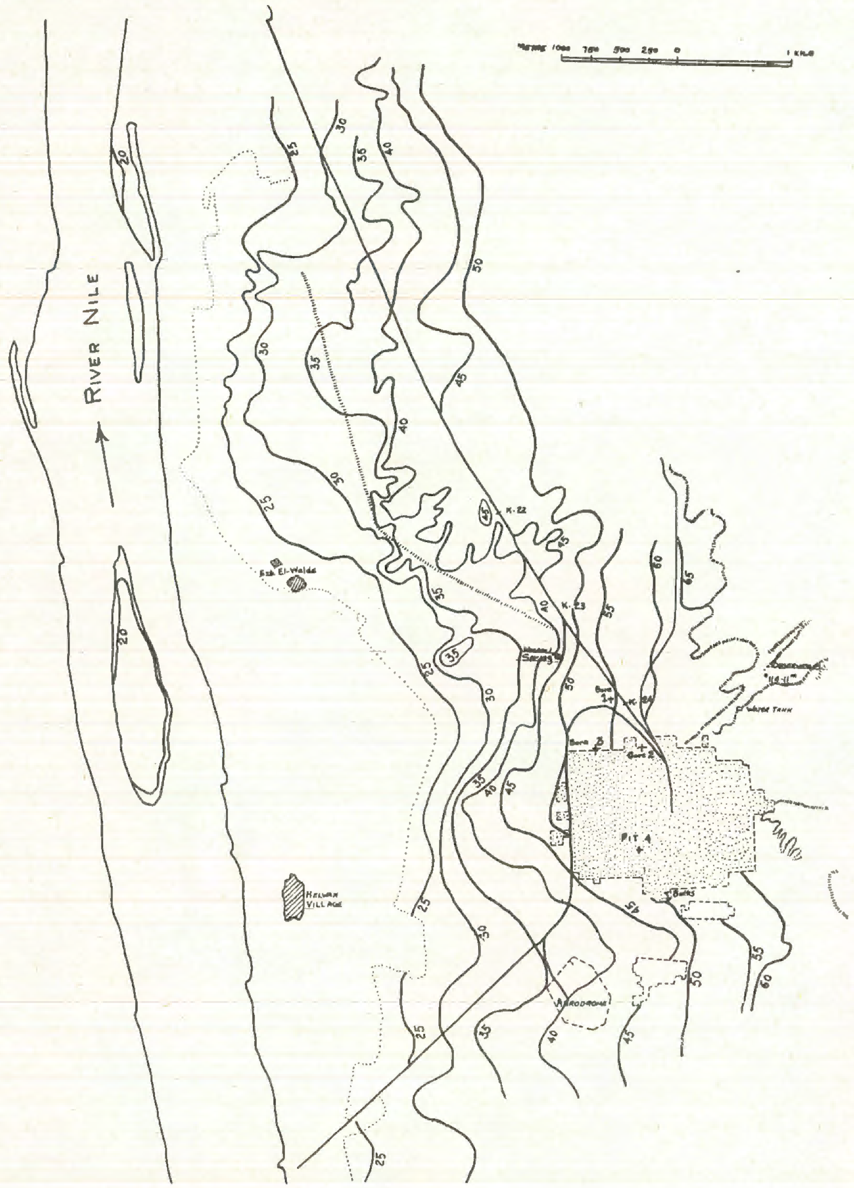

Fig. 2. Contoured Map of Helwan.

THE CLIMATE OF HELWAN

A report on the climate of Helwan, written by L. J. Sutton and based on meteorological observations of fifteen years (1906-1920), was published by the Physical Department, Ministry of Public Works, Egypt, in 1926.

A period of fifteen years is sufficient to give a fair idea of a climate like that of Helwan. The following is an extraction from that report :—

« The climate of Helwan is essentially of the Saharan desert type; its main characteristics are as follows :—

« There is a short winter, December to February, in which the nights are cold (about 9° C. on the average) while in the absence of fresh winds the days are comparatively warm (about 20° C.) On the occasions of windy days in the winter, whether the wind is northerly coming from the Mediterranean, or southerly coming from the desert,—except,—in the latter case, towards the end of the winter—the daytime also is appreciably cold, the weather during a spell of southerly winds generally being the colder. The temperature never falls to freezing point, the lowest temperature ever recorded being 1.6° C. The humidity, which is highest during the winter, is then less than 60 per cent; occasionally mist forms in the early mornings but it is almost invariably dissipated by the sun before 9 o'clock. The sky is on the average throughout the day less than half covered with cloud, and nearly eight hours of sunshine are enjoyed. Normally there are only three days of rain in each of the winter months and as a rule the rain falls in the form of light showers, although sometimes thunderstorms occur and very heavy rain (over 20 mm.) may be recorded».

« Drizzly weather is very rare and never lasts more than a day or so».

« There follows a period of transition from these winter conditions to those of the summer, which commences in June and lasts until the end of September. It is during this period of transition—March to May—that Khamsin weather is frequently experienced. This weather is caused by the approach of a depression from the western desert and

4.

heralded by an easterly wind and sky at first practically clear, with cirrus cloud developing. The humidity rapidly falls and the night is warm. With the approach of the depression the sky becomes overcast with cirro-stratus and alto-stratus, while the wind veers towards the south and strengthens, usually bringing with it clouds of sand and dust, although sometimes this wind is only a gentle breeze and little sand is raised. These sandstorms may last only an hour or so or may persist throughout the day. The air is oppressive, very dry (the relative humidity may be even as low as 10 per cent) and hot, the temperature frequently rising to 38° C. (100° F.) or more. These conditions do not often last for more than two or three days, and with the passage of the depression the wind very quickly veers to the north-west, the air rapidly becomes much cooler and damper and the atmosphere clearer; most of the stratified clouds disappear to be succeeded as a rule by some cumulus; there may be shower of rain, and the weather ceases to be oppressive. During the period March to May there are on the average rather more than three days of cool northerly winds and pleasant conditions to one of hot southerly winds».

« From June to August there are more than twelve hours of sunshine a day. The temperature reaches 35° C. on the average during the daytime and falls to about 21° C. at night. Towards the end of spring and in the early part of summer temperatures of 40° C. are not uncommon and on two occasions a temperature of 46° C. (115° F.) has been recorded. The wind is almost invariably from the north and this has a tempering effect upon weather which even so is too hot to be really enjoyable. In May the air is very dry, the relative humidity being about 40 per cent., while in the summer the value is 50 per cent. The evenings are often unconformably hot but are rarely very damp. The summer is rainless, and in fact there is hardly ever any rain from May to October inclusive».

« Helwan has an advantage over Cairo in addition to that due to its drier atmosphere, for in the summer the wind is strongest in Cairo at 5 o'clock in the evening and rapidly drops towards midnight whereas at Helwan the wind velocity does not reach its maximum in the summer until 9 o'clock in the evening. The effect of a breeze in rendering the

hot summer evenings and nights less trying is by no means negligible.»

« There are eleven hours of sunshine a day in September; the temperature extremes average 32° C. at night, and conditions are free from disturbances, so that this month properly belongs to the summer period. The weather is appreciably cooler in October—although a temperature of 40° C. (104° F.) has been recorded at sometimes or other in every month from April to October inclusive—and there is a distinct increase in cloud amount, which even then amounts only to two—tenths, with ten hours of sunshine. By November the average temperature falls to 25° C. by day and 14° C. by night, i. e. the days are 3° C. cooler than in April while the nights are the same. There are nearly nine hours of sunshine. The relative humidity is 55 per cent.»

« Although fairly hot spells are possible in either month, April and November are the pleasantest months in the year, and although of course there is no « feeling of spring» in the air in November nevertheless this month is rendered more pleasant than April by reason of the absence of Khamsins with their hot wind and dust-storms. This is a fact which seems to be overlooked by Europeans who propose wintering in Egypt; the tourist season does not commence until the middle of December, thus cutting out the best weather Egypt can give.»

« The climate of Helwan in the winter is such,—hardly any rain, nearly eight hours of sunshine a day, a dry atmosphere, pure desert air—that it is particularly suitable for invalids. In the summer the weather is too hot for people in a weak state of health and there is considerable sun-glare from the sand.»

TOPOGRAPHY OF HELWAN DISTRICT

Helwan town—as stated above—is situated at the foot of the hills which border the Nile Valley on its eastern side. The country to the north, north-east and east of Helwan is very hilly and much dissected. Gebel Hof, about 5 km. to the north of Helwan, attains a height of 314 m. above sea-level; another promontory, about 6 km. north-east of Helwan, reaches a height of 310 m. above sea-level and a third one, about 10 km. east-north-east of Helwan, attains a height of 342 m.

above sea-level. The ground to the south and south-east of Helwan is less hilly but also dissected; while the ground to the south-west, west and north-west slopes towards cultivation level.

The contoured map Fig. 2 shows a gentle slope of the ground towards the north-west, a steeper slope towards the west and a gentle slope towards the south-west. The natural drainage of Helwan town, is therefore, towards the north-west, west and south-west.

The 60 m. contour-line runs from the north through the middle of Helwan town and comes out at its south-eastern corner.

Wadi Hof meanders in a deep valley from east to west and debouches into the plain north-west of Helwan. Wadi Abu Silli—with its tributaries—rises to the east of Helwan; it runs in a south-westerly direction and finally opens into the plain south-west of Helwan.

GEOLOGY OF HELWAN DISTRICT

Figure 3 is a geological map of Helwan district. Different formations appear on this map; they are—from old to new—as follows:—

1) Middle Eocene.
2) Upper Eocene
3) Plio-Pleistocene.
4) Pleistocene and Recent
5) Alluvium.

1. The Middle Eocene.—The oldest formation which appears in Helwan district is the Middle Eocene formation. It consists of a white, massive, more or less compact limestone passing downwards into a building limestone and finally into a limestone full of *Nummulites gizehensis*.

This formation outcrops east of Helwan and extends to the north and south of it along the Nile Valley.

2. The Upper Eocene.—This formation consists mainly of sandy limestones and calcareous sandstones passing downwards into gypseous clays.

Rocks of this formation are found east-north-east of Helwan at a distance of 7 km. dropped down between two—more or less—parallel faults.

3. The Plio-Pleistocene.—Deposits belonging to this formation are found in an isolated outcrop to the south-east of Helwan and at a

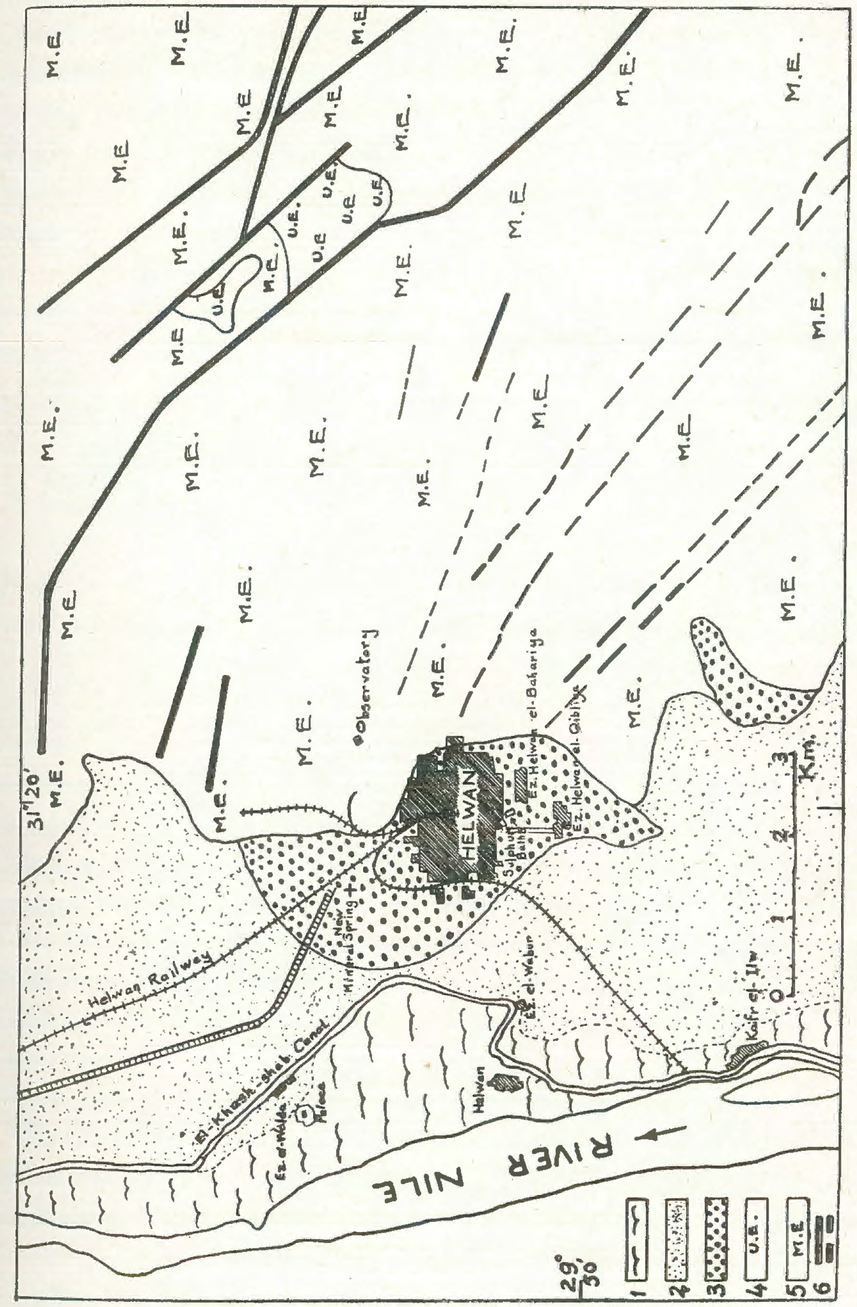

Fig. 3. Geological Map of Helwan District. 1. Alluvium (Cultivated Lands). 2. Pleistocene & Recent. 3. Plio-Pleistocene. 4. Upper Eocene. 5. Middle Eocene. 6. Faults (Traced, Inferred).

distance of 4 km. from it. They also form the top part of the plateau on which Helwan town and the two «Ezbas» to the south are built.

In the former locality, the deposits are composed of ferruginous coarse sand containing flints and fossil wood with occasional bands of flints and limestone pebbles passing southward to a false-bedded sandy marl with bands of consolidated ferruginous sand. The deposits are capped—here and there—by a conglomerate composed mainly of limestone pebbles and few flints.

In the latter locality, the deposits are mainly yellow and brown coarse sands with grey, sandy marl.

4. The Pleistocene and Recent.—These deposits constitute the gravel terraces and the wadi fill; they cover the areas to the north and south of Helwan. They are composed—mainly—of limestone pebbles, of varying sizes and of local origin, embedded in a sandy matrix.

5. The Alluvium.—Alluvial deposits cover the surface of the ground adjacent to the River Nile; they form the cultivated lands and have been deposited by the flood waters of the Nile in recent ages.

TECTONICS

In Helwan district, there are two systems of faulting (see geological map, figure 3). The first and important system comprises major faults trending in a north-west-south-east direction while the second system comprises faults trending in a more or less east-west direction.

The faults—shown on the above-mentioned geological map in continuous thick lines—have been traced by the writer in the field; some of these faults have a drop of more than 50 m. The writer has not been able to trace the faults—shown in a discontinuous line—to the south-east of Helwan although they appear on a map by A. Buxtorf dated 1910. These faults run in a N.W.-S.E. direction and have been represented by one line on the 1 : 1.000.000 Geological Map of Egypt published in 1928.

The fault that runs to the south-eastern corner of Helwan town has been mentioned by Mr. John Wells in an unpublished note written in

June 1909 concerning «Petroleum indications in the neighbourhood of Helwan». He refers to it as a «slight fault or dislocation» and adds that «The fault itself does not indicate any considerable dislocation, the total visible movement nowhere amounting to more than about 25-30 feet».

About the same time and dealing with the same subject, Dr. W. F. Hume, then superintendent of the Geological Survey of Egypt, wrote as follows—in an unpublished report—about the area to the south-east of

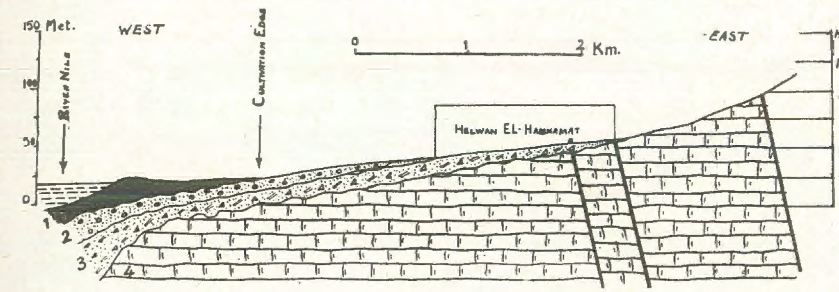

Fig. 4. Geological Section at Helwan El-Hammamat.
1. River Alluvium. 2. Pleistocene & Recent (Gravel & Sand). 3. Plio-Pleistocene (Coarse Sand & Sandy Mart). 4. Middle Eocene limestone.

Helwan :—«The ground has been obviously fractured, there being a well-marked fault on the western side; the throw of the fault being determined by the fossil evidence to be about 8 m. There is also evidence of a cross fault and minor fractures. No marked line of disturbance bounds the eastern side».

On the whole, it can be stated that faults and fractures seem to abound in the neighbourhood of Helwan.

THE STRATA BENEATH HELWAN

The Plio-Pleistocene deposits forming the top part of the plateau on which Helwan is built have been described above. A geological section running from west to east at the southern end of Helwan town has been drawn (see figure 4) from data available at the Geological Survey of Egypt. The figure shows the Plio-Pleistocene deposits resting on an uneven surface of Middle Eocene limestone.

Details of the strata beneath Helwan as revealed by the few pits (see map figure 2) put down at various points are as follows :

Pit No. I.—This pit is near the Cairo-Helwan railway line; it lies to the south-east of the new mineral spring and at a distance of 525 m. from it. The ground-level at the site of this pit is 54.22 m. above sea-level; the succession of the strata from top downwards is as follows :

DEPTH IN METRES	NATURE OF STRATA
0.00 to 0.30...........	Sand
0.30 to 2.00...........	Consolidated gypseous sand
2.00 to 2.25...........	Sticky clay
2.25 to 2.35...........	Water-bearing sand
2.35 to 3.15...........	Sticky clay
3.15 to 4.25...........	Sand
4.25 to —	Solid limestone,

Pit No. II.—This pit is to the east of Tewfiq Palace Hotel; it lies to the south-east of the new mineral spring and at a distance of 1125 m. from it. The ground level at the site of the pit is 57.67 m. above sea-level. The succession of the strata from top downwards is as follows :—

DEPTH IN METRES	NATURE OF STRATA
0.00 to 5.80...............	Sandy gypseous layer with patches of clay
5.80 to —	Solid limestone.

Pit No. III.—This pit lies to the south-south-east of the new mineral spring and at a distance of 875 m. from it. The ground level at the site of the pit is 53.46 m. above sea-level and the strata passed through are as follows :—

DEPTH IN METRES	NATURE OF STRATA
0.00 to 2.50...............	Clayey sand
2.50 to —	Solid limestone.

Pit No. IV.—This pit is situated in the southern part of Helwan town at the intersection of Shari' Raghib Pasha and Shari' Abdel-Rahman Pasha. The ground level at the site of the pit is roughly 54.000 m. above sea-level and the strata passed through are as follows :—

DEPTH IN METRES	NATURE OF STRATA
0.00 to 2.50...........	Coarse sand with irregular patches of clay.
2.50 to 3.00...........	Marl with limestone fragments
3.00 to —	Solid limestone.

Site of the new mineral spring.—The new mineral spring lies to the north-north-west of Helwan railway station and at a distance of 1800 m. from it. The ground level at the site of the spring is roughly 45.000 m. above sea-level and the strata passed through are as follows :—

DEPTH IN METRES	NATURE OF STRATA
0.00 to 4.00............	Coarse-grained consolidated sand
4.00 to 4.50............	Compact clay with limestone fragments.

The limestone base was not recorded here.

From the records of the strata of the above few pits, it is observed that the maximum thickness of the deposits overlying the Eocene limestone is found at pit No. II and amounts to 5.8 m. The deposits are mainly sands with clay patches and thin bands of marl or clay.

Underlying the Plio-Pleistocene deposits mentioned above are beds of the Middle and Lower Eocene formations. These beds consists of white or grey limestones, marly limestones, gypseous marls and shales or clays. The maximum thickness of these beds amounts to about 700 m.

Below the Eocene formation are beds of chalk or white limestones, phosphatic limestones, marls and shales belonging to the Cretaceous formation. The maximum thickness of these beds amounts to about 950 m.

Beneath these latter beds is the Nubian Sandstone Series consisting of sandstones alternating with shales or clays.

It is to be noted that, in Egypt, the Nubian Sandstones are water-bearing while the overlying Cretaceous and Eocene formations are not water-bearing inspite of the fact that the rocks forming most of their beds are porous enough.

From the above it may be observed that the total maximum thickness of the strata lying between the ground surface of Helwan and the top surface of the water-bearing Nubian Sandstones amounts to about 1650 m. In other words, if the Nubian Sandstone water is to be tapped at Helwan it is expected to be struck at a depth of about 1650 m.

THE SULPHUR SPRINGS

From the above historical part, it is observed that the sulphur springs have been known since 1850 that is more than a hundred years ago. Various scientific committees have been appointed to examine their waters. The chemical composition of these waters have been determined and their various merits and medical qualities have been proved.

Of the early chemical analyses of the waters of the sulphur springs are those made by Gastinel, Salem Pasha Salem, D. H. Richmond, Dr. Kuppers and Professor Attfield; the results [1] of these analyses are tabulated (table I) as follows :—

TABLE I. — HELWAN SULPHUR SPRINGS
(FORMER ANALYSES)
(*Calculated in parts per million*)

	Gastinel	Salem Pasha Salem	D. H. Richmond	Dr. Kuppers	Attfield
KCl	—	—	32	278	292
NaCl	3.200	3.200	5.624	8.129	5.069
$CaCl_2$	188	188	239	—	—
$MgCl_2$	1.812	1.818	1.004	—	—
Na_2CO_3	—	—	—	966	—
$CaCO_3$	560	560	—	—	825
$CaSO_4$	240		1.151	2.805	69
$MgSO_4$	—	—	447	610	—
SiO_2	—	—	15	—	29
Fe (Compounds)	—	—	14	—	—
Fe (Oxide)	—	—	—	12	—
Fe + Al	—	—	—	—	16
Org. matter	—	—	—	—	—
H_2S	44	44	—	—	92
CO_2	120	120	12	40	—
N	—	—	—	—	—
Total	6.164	5.930	8.538	12.840	6.392

[1] *Les Eaux d'Egypte,* par A. AZADIAN, tome premier, Le Caire 1930.

During the years 1910 and 1911 an investigation on some of Helwan wells and springs was carried out by Mr. G. S. Laird Clowes of Helwan with the cooperation of the Geological Survey of Egypt and the Government Chemical Laboratory. The sites of these wells and springs are shown on map (figure 5) and the following table II gives some notes and remarks on them as well as the analyses of the waters of some of them :—

(*See Table II on the page 16-17*).

From the above table II and the map figure 5, it is clearly seen that the sulphur springs are restricted to the southern and south-western region of Helwan town while the mineral springs are confined to the area north-west of it.

Comparatively recent (1919-1926), chemical analyses of the waters of some sulphur springs are those carried out at the Public Health Laboratories and recorded by A. Azadian in « Les Eaux d'Egypte » published

TABLE II. — INVESTIGATION OF SOME OF HELWAN WELLS & SPRINGS

(CARRIED OUT IN 1910)

Well. No.	Water Level m.	Ground L. m. Approx.	Temp.	Total Solids p.p.m.	Chlorine p.p.m.	Total Sulphur Compounds Sulphuric Anhydride	Sodium Carbonate	H_2S.	
1	51,07	53	23° 8	5.908	2.430	629	P. (Small Amount)	Absent	Covered well in constant use
2	52,90	58	20° 5	10.836	4.350	1.039	P. (Small Amount)	Absent	Well — not much used
3	50,58	51	23° 5	25.126	10.680	2.728	P. (Small Amount)	Absent	Masonry Well — Wide & shallow — not much used
4	48,72	49	—	—	—	—	P. (Small Amount)	Absent	Small water-hole
5	—	53	—	—	—	—	P. (Small Amount)	Absent	Small water-hole
6	48,37	52	24° 9	9.312	3.760	885	P. (Small Amount)	Absent	Stagnant-unprotected
7	—	52	—	—	—	—	P. (Small Amount)	Absent	Stagnant-unprotected
8	44,81	45	—	—	—	—	P. (Small Amount)	Absent	Well
8a	44,50	45	28°	23.570	11.460	1.053	P. (Small Amount)	Absent	Well — Stagnant — unprotected
9	48,48	50	26° 2	9.040	3.820	601	Absent	Absent	Well-flowing with a constant small stream-strong smell of Sulphur
10	48,12	50	31° 5	6.430	2.860	533	Trace	Present	Well-flowing with a constant small stream-strong smell of Sulphur (Mens' Bath)
11	48,09	49	31° 4	—	—	—	Trace	Present	Well-flowing with a constant small stream-strong smell of Sulphur (Women's Bath)
12	49,96	51	31° 0	6.406	3.090	548	P. (Small Amount)	Present	Well flowing with a large stream-strong smell of Sulphur (Bath Establishment)
13	50,15	—	22°	5.456	2.120	450	Trace	Present	Open Well
14	48,83	—	25°	4.890	2.220	454	P. (Small Amount)	Abundant	Open. shallow well giving a constant small stream
15	50,90	51	23° 3	5.756	2.420	381	Absent	Absent	Unprotected, stagnant pool
16	51,32	—	—	—	—	—	Absent	Absent	Well in Dr. Hobson's garden
17	44,85	—	—	—	—	—	Absent	Absent	Pool, west of the Railway
18	46,71	—	—	—	—	—	Absent	Absent	Stream-west of the Railway
19	45,18	50	—	—	—	—	Absent	Absent	Pocket of water in dry stream-south of Cook's Power House.
20	50,72	52	23°	—	—	—	Absent	Absent	Spring-south of Ezb. el-Bahariya
21	51,43	51	23°	—	—	—	Absent	Absent	Spring-East of Ezb. el-Qibliya
22	49,51	50	21°	—	—	—	Absent	Absent	Spring-S. E. of Ezb. el-Qibliya
23	—	51	21°	—	—	—	Absent	Absent	Water-hole.

by the Department of Public Health in 1930 and these are as in the following table III :—

TABLE III. — HELWAN SULPHUR SPRINGS
(RECENT ANALYSES)
Calculated in parts per million

	Company's Bath			Gvt. Baths	
	Large	Spring	Small Spring	Men's Bath	Women's Bath
	1919	July 1925	July 1925	June 1926	June 1926
Water Temperature	—	32°	32°	32°	33°
Air Temperature	—	27°	27°	25°	34°
Fixed Residue at 110° C.	6.140	6.148	6.112	6.270	6.280
Alkalinity	33°	34° 5	34° 5	33° 5	34°
Chlorine	2.815	2.804	2.847	2.911	3.017
Chlorine as NaCl	4.638	4.621	4.691	4.797	4.972
Permanent Hardness	—	1.181	1.130	1.120	1.100
Free Ammonia	—	—	—	10	10
Album. Ammonia	—	—	—	0,1	0,1
Nitrites	Nil	Nil	Nil	Nil	Nil
Nitrates	Nil	Nil	Nil	Nil	Nil
Silica as SiO_2	22	34	46	38	34
Sulphates as SO_3	466	449	441	429	441
Calcium as CaO	437	435	430	460	452
Magnesium as MgO	299	312	308	308	310
Iron as Fe	—	0,9	0,6	—	—
H_2S	64	52	56	52	52

The latest chemical analysis of any of the sulphur springs has been carried out early in 1951 on the water of the large spring of the company's baths. The result being as follows :—

Total Soluble Solids at 110°	6080 parts per million
Free Ammonia	4.4 parts per —
Albuminous Ammonia	2.4 parts per —
Nitrates	Nil parts per —
Nitrites	Nil parts per —
Iron	Nil parts per —
Hydrogen Sulphide (H_2S)	43.45 parts per —

It is of interest to mention here that a severe earthquake has taken place in Egypt on the evening of the 26th June 1926. This earthquake has brought into existence a new sulphur spring quite close to that supplying the Government women's bath.

This incident shows the connection between faults due to earth-movements and the sulphur springs in Helwan area (see later on « The origin of the water of the springs»).

The water of this new spring is proved to be practically identical with that of the spring in the Government women's bath as shown by the following chemical analyses :

	Calculated in parts per million	
	New Sulpher Spring	Sulph. Spring supplying Gvt. Women bath
Fixed Residue at 110° C	6260	6320
Alkalinity (French Degree)	32.5°	32.5°
Chlorine	2840	2840
Chlorine as NaCl	4680	4680
Permanent Hardness $CaCO_3$	1140	1140
Free Ammonia	10	10
Albuminoid Ammonia	0.16	0.16
Nitrites	Nil	Nil
Nitrites	Nil	Nil
Sulphates as SO_3	449	422
Calcium as CaO	380	370
Magnesium as MgO	315	320
H_2S	32	52

THE WATER OF THE SULPHUR SPRINGS

The water coming out from the sulphur springs is clear and colourless and has a strong taste and a distinguished smell of hydrogen sulphide. It has a temperature which varies between 32° and 34° C. while the air temperature ranges from 11° to 34° C.

The chemical composition of the waters of the various sulphur springs are practically identical.

The high temperature of the water of the springs indicates that the water is coming from great depths; while its salt and mineral content indicate that it has encountered strata containing these salts and minerals. (See later under « The Origin of the water of the springs»).

The amount of water discharged by the sulphur springs has been estimated by various authors at different times. The earliest estimation has been given as 700 m. cube per day; Dr. Page May in 1901 has estimated the discharge from three principal sulphur springs at about 260 m. cube per day. In December 1948, the discharge of the sulphur springs at Helwan has been *measured* by the officers of Helwan Tansîm—at the request of the committee appointed for the development of Helwan town—as follows :—

The springs in the Company's bath......	= 254	metres cube per day
The Government Men's bath............	= 63	— —
— Women's bath.........	= 72	— —
Spring south-western part of Helwan	= 14	— —
Total......	403	— —

The water of the sulphur springs of Helwan has certain medicinal and curative qualities and has been compared with waters from various European springs.

THE MINERAL SPRINGS

The mineral springs in Helwan district were known to the Geological Survey of Egypt—as mentioned above—since 1910 but none of them was of any importance. It was not until May 1939, when the officers of the Egyptian State Railways were digging a railway cutting to the north-west of Helwan, that they came across the new mineral spring.

From map figure 5 and table II, it is noticed that the mineral springs are confined to the area north-west of Helwan town.

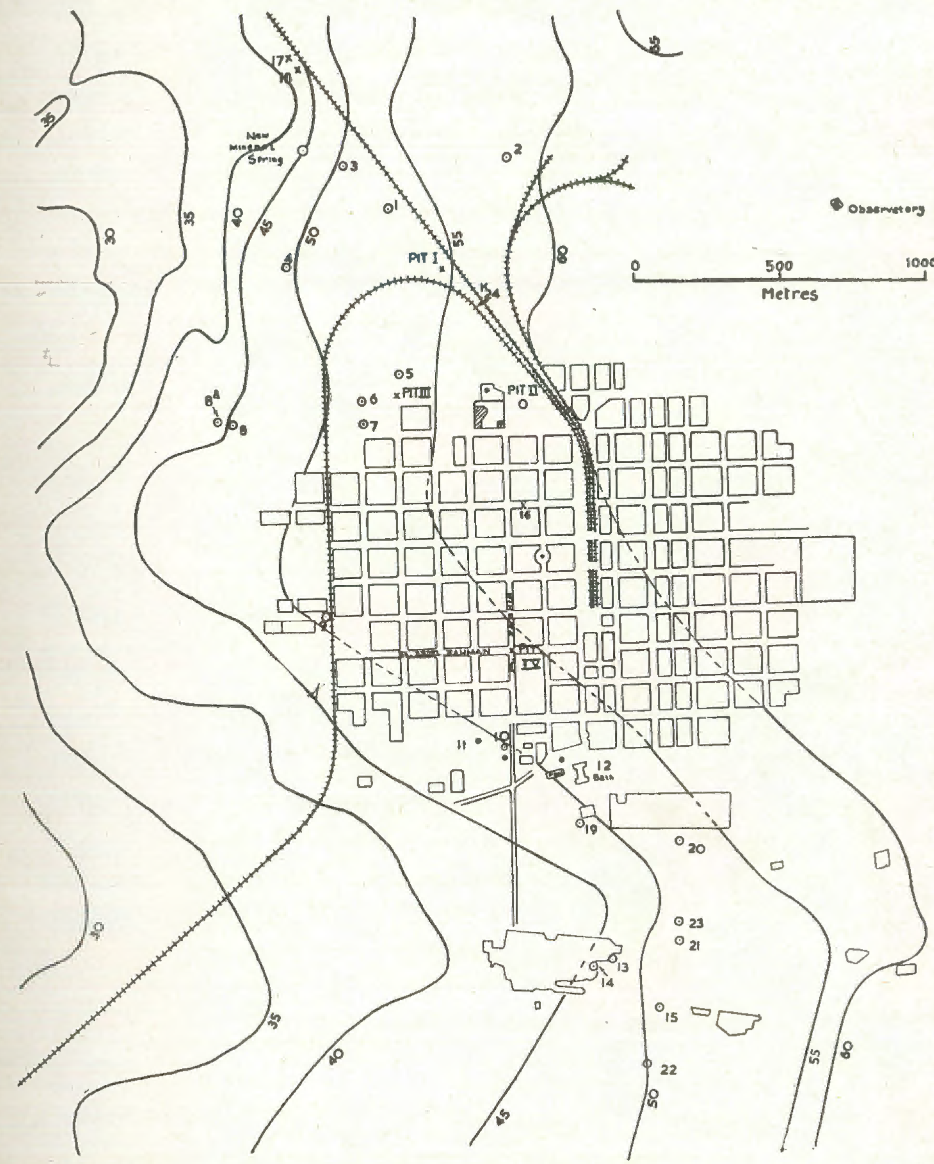

Fig. 5. Map Showing Sites of Some of Helwan Wells & Springs.

THE NEW MINERAL SPRING

This spring was encountered when digging a railway cutting in 1939.

On Monday the 22nd May 1939, Dr. H. H. Rashid chief chemist of the Public Health Laboratories and the writer paid a visit to the area. At that time the spring was of the nature of a small hole—in the bottom of an abandoned railway cutting—from which the water was coming out at a good rate (guessed to be 20 m. cube per hour). The analysis of a sample of water taken on a previous occasion by Dr. Rashid gave the following results :—

KNO_3	41 parts per million
KCl	30 parts —
$NaCl$	2690 parts —
$MgCl_2$	527 parts —
$MgSO_4$	221 parts —
$CaSO_4$	816 parts —
$CaCO_3$	125 parts —
SiO_2	18 parts —

On the 12th June 1939, the new mineral spring was visited by the Chief Inspector of Mines and the Chief Chemist of the Public Health Laboratories. Their preliminary report showed the spring to be situated at the bottom of a railway cutting and at a level of 45 m. above sea-level. Above the level of the spring, they reported a layer of compact clay with limestone fragments; this layer is more than 50 cm. thick and is overlain by a layer of coarse sand 3 to 4 m. thick. The analysis of the spring water is given as follows :—

KCl	42.2 parts per million
$NaCl$	2426.5 parts —
$MgCl_2$	611.0 parts —
$MgSO_4$	232.0 parts —
$CaSO_4$	699.0 parts —
$Fe(HCO_3)_2$	0.15 parts —
$LiCl$	Minute Traces
SiO_2	15.0 parts —
$Ca(HCO_3)_2$	285.0 parts —

In the report it is stated that the analysis of the spring water did not change during a whole month. The analyses show that the spring water is a mineral water containing abundant sodium chloride, appreciable amounts of calcium and magnesium sulphates, a small amount of iron and minute traces of lithium.

As to the source of the water of the spring, they realised the necessity of carrying out the following investigations before giving their opinion :—

1) Putting down a number of pits round the new mineral spring to penetrate the clay layer.
2) Putting down a pit 500 m. away from the spring and in the direction of Helwan Town.
3) Putting a colouring matter in the water of the pool at the Japanese Garden in Helwan Town to find out if there is a flow of underground water in the direction of the new mineral spring.

They also gave—in their report—different reasons as an argument against the spring water being seepage water.

In November 1939, the Chief Inspector of Mines and the Chief chemist of the Public Health Laboratories put down three pits Nos. I, II and III (see maps figures 2 and 5) at various distances from the new mineral spring in the direction of Helwan Town and at higher levels than the spring. The pits attained different depths but water appeared in each of them.

The fluoresceine test was carried out but no fluoresceine appeared in the spring water. This was regarded as a conclusive evidence that no seepage water reached the new spring. They also gave an analysis of the water from one of the pits and compared it with two analyses of the spring water as follows :—

	Pit No. II	New Mineral Spring	
		22.7.1939	1.12.1939
Total Solids	7.960	4.111	4.200
Alkalies	122	180	178
Chlorine	4.130	1.956	1.980
Calcium	511	274	291
Magnesium	297	169	170
Sulphates	762	582	546
Nitrates	41	Trace	Trace

The State Domains Administration in collaboration with the Mines Department has built a chamber over the limestone rock surface at the outlet of the new mineral spring and thus preventing the spring water from mixing with other waters flowing through the porous beds on top of the Eocene limestone. A four-inch pipe was fixed between this chamber and a second distributing chamber from which smaller pipes connected with the main four-inch pipe-lead to the drinking fountain, to the swimming pool and to the drain leading into the Khash-shab Canal.

The following table IV contains three complete chemical analyses of the water of the new mineral spring. The first chemical anylysis has been carried out at the Chemical Department on the 17th July 1939; the other two chemical analyses have been carried out at the Public Health Laboratories, the former in January 1940 and the latter early in 1951.

TABLE IV. — HELWAN NEW MINERAL SPRING

Complete Analyses calculated in Parts per million

	Chemical Department 17.7.1939	Public Health Laboratories	
		Jan. 1940	1951
Nitrates (NO_3)	Trace	4,4	Nil
Nitrites	—	—	Nil
Chlorine (Cl)	1.959	1.980	1.980
Fluorine	—	—	2,5
Iodine (I)	—	(P P B) 0,8	(P P B) 0,8
Sulphates as SO_4	582	546,7	546,5
Carbonates CO_3	105,6	—	—
Potassium (K)	—	33,1	33,1
Sodium (Na)	—	975	975,0
Alkalies as (Na)	1.001,4	—	—
Lithium (Li)	Nil	—	—
Calcium (Ca)	274,3	291,2	291,2
Magnesium (Mg)	168,6	170,5	170,5
Iron (Fe)	Trace	0,07	0,07
Arsenic as AsO_3	—	(P P B) 0,8	(P P B) 0,8

Silica as SiO_2	20	18	18
Phosphate	—	Nil	Nil
Lead	—	Nil	Nil
Manganese	—	Nil	Nil
Copper	—	Nil	Nil
Aluminium	Trace	Nil	Nil
Carb. diox. CO_2	—	15	15
Alkalinity Phenol	—	Nil	Nil
Alkalinity Meth. Orange	—	178	178
Permanent Hardness	—	1.088	1.088
Free Ammonia	—	—	—
Album. Ammonia	—	—	—
P H	—	7,2	7,2
H_2S	Nil	—	—
Total Solids	4.120	(180°)4.160	(180°)4.160
SiO_2	20	18	18
KNO_3	—	7,3	Nil
KCl	—	75,8	62,1
NaF	—	7,2	7,2
NaI	—	(P P B) 9,3	(P P B) 9,3
NaCl	2.531,3	2.470	2.470
$MgSO_4$	116,1	98,3	98,3
$MgCl_2$	569,2	604	604,0
$CaSO_4$	693,3	663	663
$CaCO_3$ bound as Calcium Bicarbonate	176	177,5	177,6
$Fe(HCO_3)_2$	—	0,22	0,22
$NaHAsO_4$	—	(P P B) 0,8	(P P B) 0,8
LiCl	—	—	—
Radio Activity	—	Not yet estimated	Six Units

The water of the new mineral spring is alkaline with abundant sodium chloride; appreciable amounts of calcium sulphate, magnesium chloride, magnesium sulphate and calcium carbonate; and a small amount of iron.

The water of this spring is thus a mineral water differing in character from the sulphur springs; it has been compared with Carlsbad and other such like mineral water. At present, it is used for drinking purposes and for bathing. The water is said to be beneficial in

gastro-intestinal troubles and in liver diseases and is also said to have a laxative action.

The early analyses of the water of the spring show the presence of some nitrates or traces of it; this is indicative of contamination. The chief chemist of the Public Health Laboratories states that the analyses of the water of the spring continued to show traces of nitrates for a whole year starting from the date of the spring's appearance; but ceased to do so after that as evidenced by later analyses up to the year 1951.

The presence of some nitrates in the water of the new spring at the early stages of its appearance is only natural in the case of Helwan district. Here the water of the spring coming up the fault in the Eocene limestone must have been in connection with the other waters flowing through the porous layer overlying the limestone. This state of affairs is bound to come to an end when the water of the spring is escluded from the water in the porous layer and that is what happened; although it took nearly a year to get rid of the nitrates.

Other Mineral Springs

Other mineral springs are shown on map (figure 5); two of these have been formerly examined and their waters analysed by the Public Health Laboratories.

The first spring is known locally as « Bir el-Hadîd » [1] on the assumption that its water contains some iron compounds; the chemical analysis, however, proves that the water does not contain any iron.

The second spring is located near the Cairo-Helwan railway line at Kilo. 24.

[1] Late in 1951, the writer, has not been able to locate the site of this well. It is to be noted that in 1925 the officers of the Public Health Laboratories have found this well to be sanded up; they had to dig a layer of sand two metres thick before they could get a sample of the water. It is probable that the well has been sanded up again.

The following are two analyses of the waters of these springs calculated in parts per million :—

	Bir el-Hadîd		Spr. at K. 24 C.H.Rl.	
	28/1/1920	7/9/1925	28/1/1920	7/3/1926
Total Solids at 100°	9.668	9.342	0.088	6.450
Alkalinity (French Degree)	16°4°	14°5°	8°8°	16°8°
Chlorine	4.756	3.869	3.550	2.556
NaCl	7.837	6.376	5.850	4.212
Sulphates as SO_3	787	1.075	—	565
Iron	Nil	Nil	Nil	Nil
Hydrogen Sulphide (H_2S)	Nil	Nil	Nil	Nil
Permanent Hardness	—	2.190	—	1.400
Free Ammonia	—	0,3	—	0,08
Albuminoid Ammonia	—	0,5	—	0,24
Nitrates	—	Nil	—	Nil
Nitrites	—	Nil	—	Nil
Silica	—	26	—	25
Calcium	—	429	—	500
Magnesium	—	252	—	310

The Origin of the Water of the Springs

There seems to be no doubt that the water supply of these springs is connected with the faults which seem to abound in the neighbourhood of Helwan (see geological map figure 3).

The high mineral content of the waters of the springs and the high temperatures of some of them clearly indicate that these waters—on their way from great depths of the earth to the surface—have traversed different formations in which minerals like rock-salt, gypsum, sulphur, etc. exist.

The Eocene limestone formation beneath Helwan is covered by a small thickness (under 10 m.) of sands with clay patches and thin bands of marl or clay (see above under « The strata beneath Helwan »). These

bands of clay or marl—generally resting directly on the Eocene limestone—manage to suppress the water of a spring coming up through a fault and prevent it from coming into the surface of the ground. This must have been the case with the new mineral spring which appeared in Helwan in 1939. If it was not for the opening of the railway cutting there, this spring would not have come to light.

If the water of a spring coming up through a fault does not encounter the clayey or marly bed, then this water would percolate into the sand and porous layer overlying the Eocene limestone until it gets a chance to appear on the surface of the ground.

As the Nubian Sandstone is the water-bearing formation lying beneath the Eocene and Cretaceous non-water-bearing formations, it seems very likely that the waters of the Helwan springs are derived from this source through the existing faults.

THE MIDDLE EAST ATTRACTIONS IN WORLD POLITICS

BY

M. B. HEFNY

THE MIDDLE EAST DEFINITION

The term « Middle East» is a political one framed at the beginning of the Second World War. It was originally coined by Great Britain and came into use as a consequence of the establishment of the Middle East Command over the area extending from Libya to Iran. The Command became a joint British-American operation. It is the two great western powers that grouped this vast area together for its significant strategic position.

However, the territorial definition of the Middle East varies according to the interest of each power and its sphere of influence. The British government, in its official publications, groups under Middle East some 20 countries in an area extending from Malta in the Mediterranean to Tripoli, Cyrenaica, Egypt, Sudan, Ethiopia, Eritrea, the Somalilands, Arabian Peninsula States, Cyprus, Lebanon, Syria, Palestine, Jordan, Iraq and Iran. Turkey is not included in the British definition. This dates back to the Second World War when it was a neutral.

From the American point of view, the definition of the Middle East is somewhat different. Some of the countries included in the British definition fade from the picture, such as, Ethiopia, Eritrea, the Somalilands and Sudan. Meanwhile, other countries, such as Turkey, Greece and even Afghanistan east of Iran, are a vital addition in this definition. From the recent developments, one can add Pakistan to the Middle East list. Pakistan now commands one of the most important positions on the eastern side of the Middle East with great potentialities for the western camp.

GEOGRAPHICAL BACKGROUND

The Middle East covers a huge area, some 3 million square miles. It is nearly the size of the U. S. A. Such a vast area is by no means homogeneous either in its land or its people. The features of the land are quite complex. Barren mountain ranges and broken plateaus are dominant. Inhospitable deserts, offering little but hardship, reign supreme. Desert and semi-desert climates are the rule throughout the whole realm, except for the Mediterranean seaboard. Consequently, a good part of the Middle East is uninhabited or very sparsely populated. Lack of water is an unsurmountable drawback.

However, the Middle East contains two world famous riverine land systems; that is, Mesopotamia and the Lower Nile Valley in Egypt noted for fertility and agricultural richness. There developed two of the most ancient civilizations in the world.

In all the Middle East, the cultivable range has been estimated to just 5 % of the total area. Thus, the Middle East has very limited natural habitable resources. The picture becomes bleaker with the knowledge that often they are not exploited to the maximum. The economy of the area as a whole is agricultural and nomadic, and primarily on the subsistence level. Cash or industrial crops are the exception. Industrial resources, raw materials and minerals—except for the recently discovered oil—are relatively scant. These limited resources are shared by some 90 millions (excluding Pakistan), with two-thirds divided between Turkey, Egypt and Iran. Although the population is sparsely distributed, there are certain areas of relatively high density, notably in the Nile Valley of Egypt.

STRATEGIC POSITION

But the Middle East possesses a priceless advantage in its geographical position. Commanding a central location in relation to Asia, Europe and Africa, it has been the cross-road between three continents and two major oceans. From the Atlantic Ocean, the Mediterranean Sea penetrates eastwards to the Middle East, while the Indian Ocean sends two wedges, the Red Sea and the Persian Gulf, from the southeast. By virture of its position and physical setting, the area of the Middle East presents a number of attractions of strategic significance : 1) Through the Middle East runs the shortest sea route from Europe to Asia, saving 10-15 days in sea traffic compared with the route around the South African Cape. 2) Across the area extends the Fertile Crescent from the eastern Mediterranean coast, through the Syrian plain, and Mesopotamia to the Persian Gulf. It lies between a mountain barrier and barren deserts, and since historical times it has been the natural avenue for communication and trade routes. 3) A focus of world air routes radiating to Europe, the Far East, Australia, East and South Africa. 4) The Straits of Dardanelles and Bosphorus connect the Black Sea with the Mediterranean. They lie within Turkey's territory between the European part of Turkey and the Asiatic Anatolia. The Straits are the key to the Black Sea entrance and exit. 5) The Suez and Aqaba isthmuses which form the land connection between Asia and Africa by way of the Egyptian gate of Sinai. Across the Suez Isthmus is the Suez Canal, the link between the Mediterranean-Atlantic and the Red Sea-Indian Ocean highway. 6) In the Middle East lies the Strait of Bab el Mandeb, the key between the Red Sea and the Indian Ocean. 7) The Persian Gulf is a waterway projecting into the heart of the Middle East and towards the leading oil fields of the region.

HISTORICAL DEVELOPMENTS

This geographic position has been the decisive factor in the encroachment of the outside powers upon the Middle East. Since the early modern period, beginning with the 17th century, Western Europe has taken the lead in extending its economic and political influence to the realm of southeast Asia, rich in natural resources. The Middle East became important in effecting the bridge to the East.

THE MIDDLE EAST, A BRITISH CONCERN : Great Britain has assumed the command in economic and political relations with the East. Soon after the chartering of the British East India Company in 1600, British

trade monopoly and political privileges were established in southeast and south Asia, notably India, Afghanistan, the Persian Gulf region, and the southern Arabian coast. The prosperous reign of the Company, lasting nearly 3 centuries, led to the founding of the greatest empire overseas, with the Middle East emerging, consequently, as the key to the Empire.

To Great Britain, the Middle East has been of primary importance, not so much for its resources, but as the central circuit in the British life line. It thus became a necessity in the British policy, to secure the Middle East and in turn secure her ties with the eastern Empire. A study of the history in the 18-19th centuries reveals how Britain manoeuvered to acquire the key posts of the Middle East within her sphere of influence. The British encroachment came about from more than one direction at practically the same pace. From British India, the British influence moved towards the eastern and southern parts of the Middle East, while from the west it progressed directly by way of the Mediterranean.

In the 18th century, British political relations were established in the Persian Gulf region. A British Residency directed from India was founded in 1763 at Bushire on the Persian coast. (The Residency was removed in 1946 to Bahrein and in August 1947, it was placed under the British Foreign Office). Then during the 19th century, Great Britain accomplished a succession of agreements with the Arab chiefs of the Sultanates and Sheikhdoms on the western side of the Persian Gulf. By the end of the century, virtually all of the small units; Sultanate of Muscat and Oman, Bahrein, Kuwait, the Trucial Sheikhdoms and Qatar were under varied forms of British protection.

A similar encroachment took place to secure the Gulf of Aden, the gateway between the Red Sea and the Indian Ocean. Britain acquired Aden in 1839 and a part of Somaliland, on the African side, in 1884. The British then extended their control to the southern coast of Arabia. The Arab chiefs there came under the 'Aden Protectorate' in 1886.

From the Mediterranean Sea, Great Britain was similarly engaged in securing footholds towards the Middle East. In 1713, Gibraltar, the gateway to the East, was ceded to Britain by Spain. A century later,

1814, Malta was taken. In 1878, Cyprus fell under British domination. Four years later, Great Britain occupied Egypt (fig. 1).

The simultaneous encroachments of Britain in the 19th century from both sides culminated in Egypt in a grip of military occupation in 1882, thirteen years after the opening of the Suez Canal. The completion of

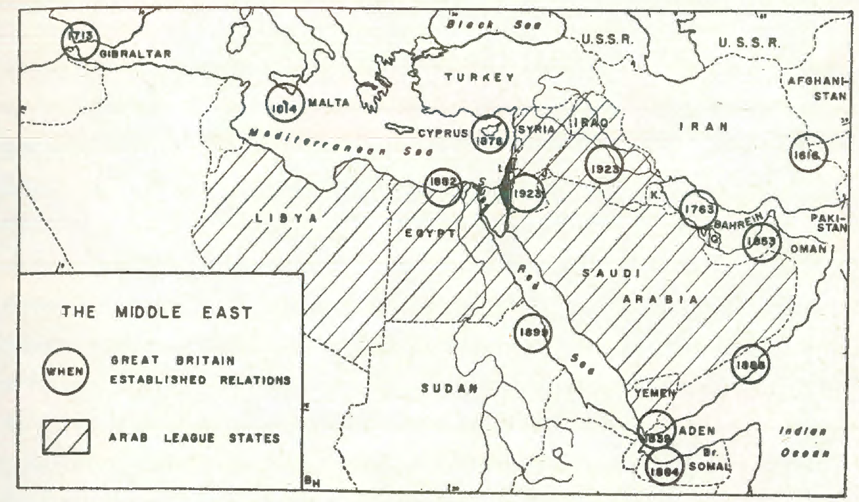

Fig. 1.

the Suez Canal was the ignition which placed Egypt and the Middle East in a position of immense strategic and economic importance relative to the British Empire.

THE MIDDLE EAST, YOUNG COUNTRIES WITH BRITISH TIES : While Great Britain was establishing her footholds, the Middle East was in a state of stagnation under the Ottoman and Persian Empires. The Ottoman Empire is of particular interest as it encompassed most of the Middle East except for Persia. It existed for about four centuries until it was formally dissolved in 1923. The Ottoman rule over this vast area was by no means complimentary to this part of the world. The inroads of decay, negligence of internal affairs and the general deterioration caused the Middle East to lag behind the outside world.

The Ottoman Empire has been kept alive that long time mainly by the western powers in order to maintain a buffer between them and Russia.

But with World War I, when Ottoman Turkey joined Germany, the tide turned. The Arab countries awakened with national movements and rose against Turkey assisting the western powers in overthrowing their bonds.

Out of the Ottoman Empire emerged most of the present countries of the Middle East. It was only after the First World War that they were established as independents by the Western Powers (notably Britain and France) with the blessing of the League of Nations. Between 1915-1920, these powers determined the fate of the region by secret agreements and open declarations.

The division of the Middle East into nations was primarily designed by Britain who got the lion's share of the successor nations. The land from the eastern Mediterranean coast to the frontier of Iran was made into units : Palestine, Trans-Jordan and Iraq were assigned to the British mandate, and Syria-Lebanon to the French. In Egypt, although British protection ended in 1922, the recognition of its independence embodied severe restrictive conditions by Great Britain. Turkey, as a new independent nation, was the only country with a head start. In 1923, Moustafa Kamal wiped out the Ottoman Sultanate, establishing the Republic of Turkey. Immediately, Turkey drifted from its Arab neighbours and began its westernization.

In Arabia, Ibn Saud of Nejd was successful in subduing the whole peninsula except for the British protected periphery and independent imamte of Yemen. In January 1926, the Kingdom of Arabia was proclaimed. This was followed by a treaty of friendship with Britain in May 1927. Yemen involved itself with Britain in the Treaty of San'a in February 1934, securing mutual cooperation. Thus, all the Arab countries and units were knit closer through British ties.

The only countries where Britain did not secure any direct rights or special privileges were Turkey and Iran. By virture of their position on the Russian front, they came under certain provisions set by the foreign powers to maintain a buffer zone. At the beginning of this century, Great Britain wielded a sphere of influence in the southern part of Iran, while Russia reserved a similar one in the north. In the case of Turkey, the western powers have always backed and assisted the country to maintain its sovereign integrity from any soviet influence. In the Montreaux

Convention of July 1936, Turkey was allowed to remilitarize, and thus have full control of the zone of the Straits.

Except for Palestine, the newly born Arab states have made continuous strides towards independence. Although, almost completely so now, strings are attached by Great Britain which take away territorial sovereignty.

Iraq was the first country where British mandate was terminated (1932) and its independence recognized. However, a Treaty of Alliance and Amity (term 25 years) reserves for Britain rights in regard to military matters and general interests. Iraq provides two sites for British air bases, in Habbaniyah on the Euphrates west of Baghdad, and in Shaibah near Basra.

In 1941, the French mandate in Syria was terminated and the Free-French power proclaimed the independence of both Syria and Lebanon. The two independent states came into existence in December 1944.

Soon after, Great Britain granted Trans-Jordan independence (1946). In 1948, a further Anglo-Trans-Jordan treaty of friendship and alliance was signed (effective 25 years). The treaty grants Britain military rights in Jordan, securing bases at Amman and Mafrak for British air forces.

In the case of Palestine, Britain terminated its mandate and passed the responsibility to the United Nations. This indiscretion led to the tragedy of Israel-Palestine.

Britain formally recognized Egypt's independence by the Anglo-Egyptian Treaty in 1936, with the provision of maintaining a small military and air force in the «Suez Canal Zone». Through events of World War II, the Suez base became the center of coordination and control of defense for the Middle East, East Africa, East Mediterranean and Indian Ocean territories. It swelled to greater proportions with the withdrawal of British forces from Palestine in 1948. Egypt's strife for the evacuation of the Suez Canal Zone by Britain met success recently. However, the agreement in process provides conditional access to the base for Great Britain.

THE WESTERN IMPACT : With the intervention of Britain and her associates since World War I, the Middle East affairs have been marked by

a strong growing influence of the Western World upon its economic and social life. Adoption of western methods in varied degrees has brought about good and misgivings. The latter disturbs the traditional Oriental elements in Middle East culture, causing unrest and increasing frustration mainly among the masses. As Britain has emerged in undisputable dominance over these countries, special rights and privileges have been gained in most of the Middle East. This situation has implied certain forms of intervention in their political affairs. A significant outcome is the growing Arab national consciousness and individualism which flares up to the extrema at times. This trend has been accelerated with the emergence of Zionist nationalism.

OIL RESOURCES, A PRIMARY ATTRACTION

Just as the Middle East, by its strategic position, became desirable to outside powers, discoveries of rich oil resources enhanced its attraction. It is the misfortune of the Middle East to be totally incapable financially and technically of exploiting these resources on its own. The sudden rise of the Middle East in oil production and reserves added flame to western intervention. Oil resources became the primary motive for encroachment for the western powers already maintaining a foothold there. Moreover, another major power, the U. S. A., has been introduced into the fate of the Middle East.

The bulk of the oil resources exists in Saudi Arabia, Kuwait, Iran and Iraq with Qatar, Egypt and Bahrein trailing. It is almost totally in the hands of the U. S. A. and Great Britain.

In production, the Middle East ranks second to U. S. A. In 1953, the preliminary figures of production of the Middle East oil fields were 121.6 million tons or 18.4 % of the world total. The U. S. A. contributed nearly 60 %, and the Carribbean region (mainly Venezuela) some 12 %. It is only in the past few years that the Middle East moved into its position overtaking the Caribbean region in oil output. The production in the Middle East increased sharply in the last five years. The increase has been constant despite the interruption of production in Iran (1951-1954) following the movement to nationalize its oil resources.

The total figures rose from 67.7 million tons in 1948 to 88.6 million in 1950 to 121.6 million 1953. The latest records of oil production show that 92 % of the whole Middle East output comes from three countries : Kuwait (35 %), Saudi Arabia (34 %) and Iraq (23 %). The production figures by countries show a terrific jump from 1948 to 1953; Kuwait from 6.4 million tons to 42.6 million, Saudi Arabia from 19.2 million to 41.5 million and Iraq from 3.4 million to 28.2 million.

This recent boom in production is not the whole story. Recently, it was revealed that the Middle East is literally flooded with oil. According to 1953 estimates, the Middle East possessed over half of the world's proved oil reserves, 8,307 million tons, or 53.3 %. This is compared to 24.5 % in the U. S. A. and 10 % in the Caribbean region. Saudi Arabia, Kuwait, Iran and Iraq account for about 97 % of the Middle East oil reserves.

Foreign interest in Middle East oil dates back to the end of the 19th century. However, industrial exploitation of oil did not come underway effectively until the first quarter of this century has passed. The western powers, being the pioneers in Middle East affairs and having the upper hand in foreign influence, have completely monopolized the exploitation of the oil. Concessions were granted by respective Middle East governments to European and American concerns in return for certain benefits according to profit-sharing agreements.

The Middle East oil resources are in the hands of 6 companies, mostly American, British and Dutch, with concessions expiring about the end of the 20th century.

1. The Anglo-Iranian Oil Company, with concessions in Iran expiring in 1993, is mainly a British concern, in which the British government acquired an interest of 56 %. It ranks among the world's largest oil concerns.

Iran's movement to nationalize the holdings of the company three years ago, brought a temporary halt to this major concern. In August 1954, an initial agreement was reached ending that dispute. The essence of the agreement is the introduction of American interest for the first time in the Iranian oil operations. A consortium of eight of

the largest oil companies in the world will undertake the concession, five of which are American, sharing 40 % of the interest in the enterprise.

2. Arabian-American Oil Company, 100 % American, operates in Saudi Arabia under a concession that expires in 1999.

3. Iraq Petroleum Company, shared equally by British, Dutch, American and French, has concessions in Iraq and Qatar expiring in 2000.

4. Kuwait Oil Company, 50 % American and 50 % British expires in 2011.

5. Bahrein Petroleum Company, 100 % American, expires in 1995.

6. Anglo-Egyptian Oilfields Ltd., a British company with the Egyptian government holding a participating interest. In 1954, concessions were granted to American concerns in the Western Desert.

The attraction of the Middle East in oil is brought about on the basis of : abundant resources, little local consumption (15 %), and the oil hunger in most of the Eastern hemisphere. In the post-war period, the Middle East oil output was geared by the American-European interests to supply the great demand for the recovery of Europe and the development of Asiatic countries. Since 1950, the Middle East emerged as the leading exporter of oil (fig. 2).

Prior to the Middle East oil boom, the deficit of the Eastern hemisphere in oil, especially western Europe, had been mostly supplied by the U. S. A. and the Caribbean region. In pre-war years, the U. S. A. was the chief exporter in world oil trade. Now, the pattern has changed drastically, U. S. A. became the chief importer of oil, with the Caribbean region as the major supplier. The Middle East, on the other hand, replaced both, the U. S. A. and the Caribbean, in supplying most of the Eastern hemisphere.

The supremacy of the Middle East in the international oil market has been built up primarily by American interests. The U. S. A. found in the Middle East a source for foreign supply by which she increasingly freed the American oil for internal use. Since World War II, the U.S.A.'s consumption of oil has been so lavish that it outpaced local production with hardly any surplus for export. By directing the flow of oil from the Middle East towards the Eastern hemisphere, the U. S. A.

took an essential step towards conserving her domestic resources. This oil policy is extremely vital to U. S. A., especially when it becomes known that, if the U. S. A. depended only on local oil resources, her oil reserves would run out in 20 or 25 years. This situation necessitated (1) supplementing its home consumption by importing oil, mainly trom the Caribbean, (2) replacing U. S. A. with the Middle East in supplying the Eastern Hemisphere, (3) securing oil resources in the Middle East (as well as in the Caribbean area) for future supply.

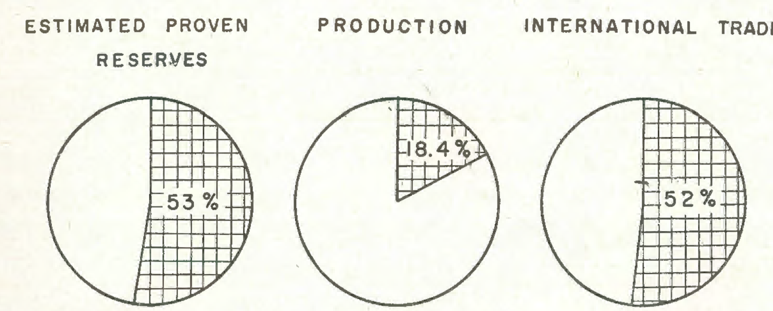

Fig. 2. Middle East Share of World oil 1953.

Soviet Share on Paper : The Soviet Union comes into the picture of the Middle East oil in the case of Iran. While Britain was granted concessions in southern Persia in 1901, rights were reserved for Russia in 1907 in the five northern provinces. But no effective operations have been undertaken there by Russia because of power conflicts and rivalries. This part of Iran, however, through some agreements imposed on the country by U. S. S. R. since post-war I, is still reserved for Soviet interests. In February 1921, by the Soviet-Persian treaty, following the occupation of Aserbaijan and Tehran by Soviet armies, Persia guaranteed not to agree to any concessions in that area without the consent of Moscow. British and American concerns tried repeatedly for concessions there, but in vain. A similar agreement was reached to further Soviet claims to exploit the northern area at the end of 1946 when Russian troops were occupying northern Iran. The withdrawal

of their troops was contingent upon provisions for setting up a Soviet-Iranian Oil Company for operation. Owing to political differences and instability, this agreement still awaits ratification by the Iranian Parliament.

* * *

Because of location and rich oil resources, the Middle East has become the focal area for countless outside interests. Its political and economic ties with the western world and its position on the frontier of the Soviet (eastern) bloc traps it between the two factions and subjects it to outside pressures. Great Britain, the great power in the Middle East for centuries has secured political and economic rights.

Traditionally, Britain is constantly advocating the advantages of alliances with the Middle Eastern countries to guard her interests and the countries involved from other foreign powers, the Soviet in particular. The U. S. S. R. has been the primary rival in Middle East affairs, especially in the border countries, Turkey, Iraq and Iran. More recently, the American influence reached the Middle East bringing a third major power into its affairs.

THE MIDDLE EAST OIL RESOURCES-SELECTED DATA

	Oil Production (thousand tons)			*Estimated Proven Reserves (million tons)*	
Country	1948	1950	1953	1951	1953
Kuwait	6.400	17.291	42.654	2.036	2.444
S. Arabia	19.260	26.904	41.566	1.348	2.426
Iran	25.270	32.259	1.366	1.722	1.722
Iraq	3.427	6.479	28.200	1.163	1.470
Qatar		1.636	4.003	130	163
Egypt	1.886	2.607	2.350	25	28
Bahrein	1.496	1.511	1.506	40	40
Turkey	3	17	28	1	11
Total	57.742	88.613	121.673	6.469	8.307
World	470.000	525.000	660.000	12.953	15.580
M.E.	12.3 %	16.9 %	18.4 %	49.9 %	53.3 %

MIDDLE EAST OIL COMPANIES

Name	Concession	Ownership
Anglo-Iranian Oil Co	1901-1993	British-American
Arabian-American Oil Co	1933-1999	American
Iraq Petroleum Co	1925-2000	British-Dutch
Kuwait Oil Co	1934-2011	British-American
Bahrein Petroleum Co	1930-1995	American

DIRECT PAYMENTS BY OIL COMPANIES TO GOVERNMENTS OF OIL PRODUCING COUNTRIES (MILLIONS OF US DOLLARS)

	Iran	S. Arabia	Kuwait	Iraq	Qatar	Bahrein	Egypt	Total
1949	50,1	66,0	11,8	7,9	—	1,5	5,0	142,3
1950	44,9	112,0	12,4	14,8	1,0	3,3	4,9	193,3
1952	—	170,0	139,0	110,0	9,0	6,3	5,8	440,1

POPULATION

Aden—80,516 (1946)
Afghanistan—About 11,000,000
Bahrein—110,000
Egypt—20,439,000 (1950)
Iraq—5,100,000 (1950)
Iran—19,140,000 (1951)
Israel—1,607,000 (1952)
Jordan—1,250,000
Kuwait—205,000
Lebanon—1,265,000 (1949)
Libya—1,124,000 (1951)
Muscat & Oman—550,000
Pakistan—75,842,000 (1951)
Qatar—18,000
Saudi-Arabia—2,000,000
Syria—3,253,000 (1950)
The Trucial States—95,000
Turkey—21,937,000 (1950)
Yemen—4,500,000 (1953)

BIBLIOGRAPHY

Cole, D. H., *Imperial Military Geography* (London, Sifton Praed & Co., Ltd., 10th ed., 1950).

—— Royal Institute of International Affairs, *The Middle East.* A Political and Economic Survey (London & New York, 1951).

FISHER, W. B. *The Middle East,* A Physical, Social and Regional Geography. (London, Methuen & Co., Ltd., 1952).

MIKESELL, R. F. & CHENERY, H. B., *Arabian Oil.* (University of North Carolina Press, Chapel Hill, 1949).

—— United Nations. Review of Economic Conditions in the Middle East 1951-1952. Supplement to World Economic Report.

—— United Nations. Summary of Recent Economic Developments in the Middle East 1952-1953. *Supplement to World Economic Report.*

THE MORPHOLOGY OF DAMASCUS

BY

DAWLAT SADEK

Damascus, the first city of Syria has a unique significance among many cities which bordes the desert of Syria and Arabia. Although only 70 miles from the shore of the Mediterranean, Damascus is essentially a city of the desert borders for, between the sands which surround it and the waters of the Levant there are physical barriers [1].

Damascus lies in the north-west corner of the Ghuta, a fertile plain, extending for roughly 150 square miles at the foot of mountains which rise on three sides of it. The city and the Ghuta have such economic integration that the urban centre and the fertile plain have been considered as one unit. The land is cultivated to the very limit of the built-up area.

Damascus is now in rapid transition from the traditional features of the past to the layout now being planned. The growth of Damascus suggests an analysis under the following headings :

1) The site and nuclear area of Damascus;
2) The Roman town;
3) The modern city.

1. THE SITE AND NUCLEAR AREA OF DAMASCUS.

The site of Damascus is very important. Owing to the out-standing fertility of its natural surroundings, the town, laying on the north-south road through Inner Syria, was able to attract the trade of North

[1] The series of plateaux and ridges culminate in peaks of over 10.000 feet in the Lebanon mountains. To the east of this coastal barrier the land slopes sharply to a depression traceable from the Gulf of Akaba to the northern borders of Syria beyond which rises another ridge of highland.

Syria and Mesopotamia, of Arabia and Persia with the Mediterranean and Egypt from the natural routes farther north and south respectively and to make itself the centre of this traffic. It was an important road junction.

The primitive site of Damascus was not a strong defence point, being without the natural advantages of the hill-top towns of the interior, such as Palmyra and Dura-Europos. To the north are the spurs of Anti Lebanon, stretching northeastwards into the desert. Four or five miles away the Jabal Kasyun rises on the north-west and shelters the plain of Damascus in the north and south while to the south the volcanic hills of Jabal Aswad and Jabal el-Mani lie about 16 miles away, and beyond them the great Lava flow of El-Lijah. They afford a certain amount of Shelter, but on the east it is quite exposed. This gravitation towards the desert was probably also the reason why the city under Roman rule never become the capital of the province.

2. THE ROMAN TOWN. REGIONAL LIMITS.

The regional development of the Roman town can only be dimly discerned but there are at least three features associated with its evolution. Firstly, as a rich agricultural centre. The Barada has created an extensive oasis, on the Syrian Desert border. Secondly, as a commercial centre. Damascus was a centre of a very heavy traffic. Thirdly, as an industrial centre. The textile industry, particulary silk weaving was the basis of the town's manufactures. There was a marked contrast between the dense population of Damascus and the sparsely settled lands of the interior plateaux.

Morphology of the Roman town

It is not easy to study the pattern of old Damascus. Although the traces of the caravan route, the temple, and the caravanserais are still recognisable, the old is so much overlaid by the new, that the topography of the ancient city becomes intelligible only when it is studied in connection with Petra and Palmyra. One can hardly be wrong however in supposing that the general plan of the town has been the same

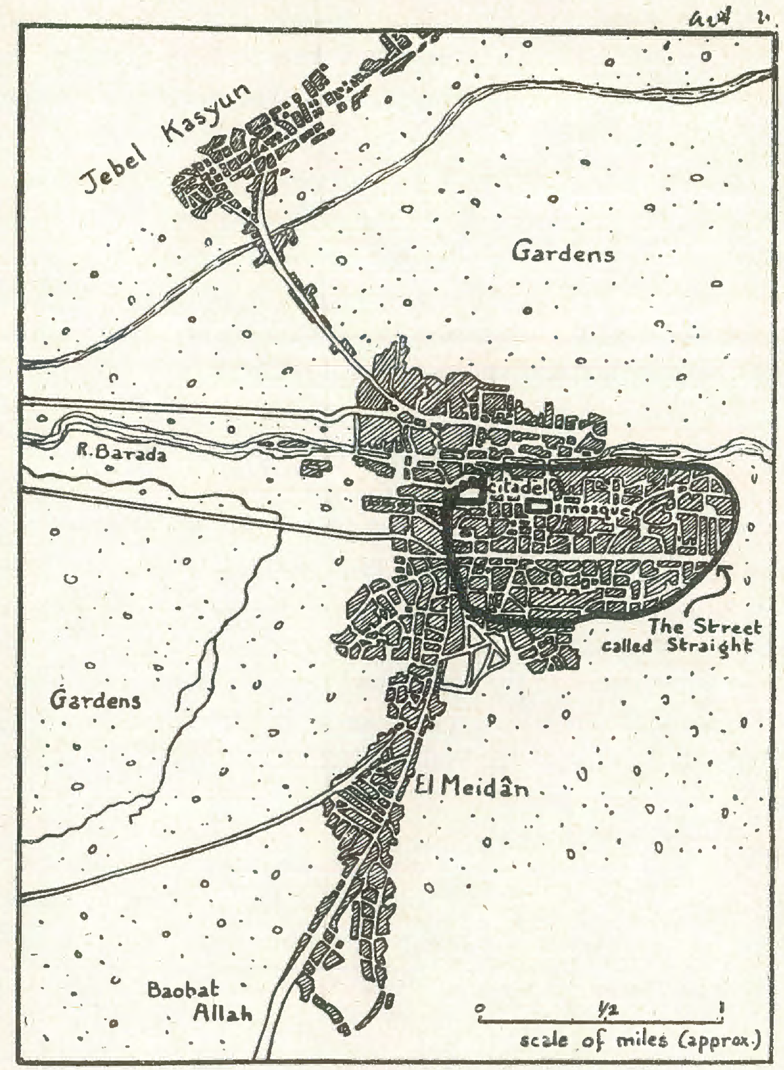

Fig. 1. Plan of Damascus
(After J. Garret).

for centuries, before even the Arab invasion, but this had certainly not brought about any radical alteration in its configuration. Since the Muslim conquest the walls and essential features of the town have been practically unchanged. The natural site of Damascus dictated its present form since Roman times. It is an elongated rectangle on the

right bank of Barada, cut through by a road along its greatest length. This road is still called the « Straight Street» [1]. The industries were grouped separately into quarters of the town, the chief commercial houses being situated near the centre, and the labourers' houses built behind, in the side streets. Narrow, irregular streets led to enclosed bazars. The narrow Lanes served a double purpose : to provide the maximum shade from the strong sun and to give a useful defence in time of war.

Such then, were the features of the Roman town, which symbolised its role as an agricultural and commercial centre.

3. THE MODERN CITY : REGIONAL LIMITS.

It has been demonstrated that the growth of Damascus was related to the use of the productive Ghuta plain. The economic development of the 20th C. emphasised this relationship : the use of the artificial fertilizers, the irrigation and drainage system, the development of road served to integrate the agricultural wealth of the Ghuta plain and the prosperity of the city on a commercial basis. The volume of passenger traffic is another indication of the city's sphere of influence.

The Morphology of the modern City

A sketch of the modern city will be a supplement to the historical survey of Damascus because the ground plan of the heart of the city has not been altered. It still remains distinctive with narrow congested streets its many mosques, and a high gross population density. The buildings are close together a typical oriental feature. Typically oriental also is the sagregation of the various arts and crafts, the tentmakers in one street, the carpenters in another, and so on, in which may be seen a reflection of the commercial element which has always played such a large part in the life of the city.

It is the centre of numerous small family workshops for the manufacture of artistic goods and furniture. Now new streets are being dri-

[1] Sauvaget (J.), *Les Monuments Historiques de Damas,* p. 3 and fig. 1.

ven through this old quarter of the town and for the first time its hidden plazas are being exposed. Peripheral to the old centre but still in the heart of the city are the magnificent buildings erected in the last half century which constitute the commercial and shopping centre. Beyond to the north west lies the new town « Al-Mohagerin», the residential quarters with their tall blocks of flats and high gross population densities, at the same time with a sense of spaciousness assorted by the broad avenues, these avenues laid out with trees and watered gardens form the basis of the city's open spaces.

The influence of religion is everywhere in evidence. Many places of worship, Christian, Jewish and Moslem, rise within the city walls [1]. The most notable is the great Mosque of the Umayyads [2], it is significant that before the rise of Islam it was the site of a Christian Church, much at which still remains [3], and earlier still probably that of the heathen temple [4]. The position of Damascus as a starting-place for the Moslem pilgrimage to Mecca has added greatly to its religious significance and has had a marked effects on its morphology. Suburbs of comparatively modern date mark the city's expansion, both on the neighbouring hills and to the north of the Barada, but the most remarkable is surely that of El-Meidan, which extends for over 2 miles southwords as far as the « Boabet Allah», so called the pilgrimage. This would seem to be a suburb which has grown up purely in response to religious influence.

Damascus is one of the very few cities in Syria that was enjoyed a flourishing past and will enjoy a hopeful future. This may be regarded as a direct result of its water-supply. It is this long continuity of the

[1] Garrett (J.), *The Site of Damascus, Geography,* 1936, p. 283-296.

[2] See Bell (G. L.), *Palace and Mosque of Ukaidir,* p. 151.

[3] The nave and aisles of the Church of St. John must have dictated the scheme of the mosque's orchards.

[4] Here, close together, lay the Old Mosque, the Church of St. John and Mu'awiya's new palace, at Khadra. The Mosque was quite distinct from the Church. From Al-Khadra Mu'awiya had direct access to the Mosque. A. von Kramer, *Culturgeschichte,* p. 119, has given a very attractive picture of life in the city of Caliph.

elements of the city's life, which have given it such a definite and complicated character and helped it to become not only an oasis, but a caravan centre, manufacturing town and Holy city.

A city which owes its important to some special factor, such as the development of trade routes in its vicinity, strategic advantages, the dominance of a foreign political power, and so on, may decline as quickly as it has arisen when the trade routes take other courses, frontier change, or political power decays, such has not been the fate of a true desert border city. Damascus was the capital of the Umayyad Empire, an empire that has completely vanished, yet the capital continued to flourish with an unbroken chain of history.

AGRICULTURAL LAND USE IN THE FAYUM DEPRESSION

BY

MOHAMED IBRAHIM HASSAN

In a previous paper, the writer has discussed the main physical elements which have radically affected the land use patterns of the Fayum depression. These elements are : Terrain, soils and water supply [1].

The depression floor slopes downwards in a northwesterly direction to lake Qarun, and consists mostly of rich alluvial land irrigated by canals that enter the depression from the Nile by way of a narrow opening through the desert hills. If a longitudinal section is made from this opening at Lahun regulator through the capital of Medinet el Fayum and Sinnuris to lake Qarun [2], the province can be devided into the broad Madinet el Fayum plateau, 20 km. in breadth, which has been built up by Nile silt brought by Bahr Yussef canal. Here, the mean slope is only 1 in 11.000, the altitude being between 23 and 26 m. above sea-level. There is then a shorter slope of 1 in 1.200 for about 15 km. to Sinnuris, and finally a very abrupt slope of 1 in 180 for the next 10 km. At the bottom of the descent is lake Qarun, its surface being 40 m. below sea-level. From the land use point of view, these low lands are always sacrificed to the high as areas covered with efflorescences and poor soils are generally bellow the surrounding fields. The

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(1) MOHAMED IBRAHIM HASSAN, *Physical elements of Agricultural land use in the Fayum Depression* (extrait du *Bulletin de la Société de Géographie d'Egypte,* t. XXVII, septembre 1954, pp. 51-64).

(2) *Map of the Nile Delta and Fayum Depression;* scale 1 : 300,000—Survey of Egypt.

cause of injury is mainly due to over-irrigation without corresponding drainage.

As far as soils are concerned, the depression floor is mainly covered with alluvial soil which is mostly identical in origin and composition with the river alluvium of the Nile valley. However, this soil is not all black and fertile, as several patches of high-lying gravel and sand are spotted here and there amidst the cultivated areas.

Regarding water-supply, agriculture of the Fayum depends entirely on the supply of irrigation water from the Nile. When Bahr Yusef enters the wide cultivated area of Fayum, it gives off numerous subsidiary canals which traverse the country in many directions, constantly splitting up into smaller branches until the water supply is divided throughout the whole area.

Most of drainage water is passed into lake Qarun by two main channels called the Wadi drain and Tamiya drain. They have been cut down in many places to the limestone below the alluvium, and have a considerable beauty owing to the combination of steep-sided cliff faces and abundant vegetation bordering water channels. According to Beadnell [1], El Wadi and Tamiya ravines were initiated by the escape of water through breaches in Bahr Yusef during flood times and have since been deepened to their present dimensions.

Based on a study of : *a*) the main physical elements which have had a radical effect on the land use and agricultural economy of the Fayum region, *b*) the detailed sheets of the Fayum Province made by the Survey of Egypt [2], *c*) agricultural rotations in selected areas over the depression, *d*) many trips of the writer in several parts of the concerned area ; an agricultural land-use map of the Fayum depression was made.

According to this map, the main agricultural regions are : *a*) rice and cereals, *b*) cotton and cereals, *c*) vegetables and fruits. Moreover, the map shows areas of agricultural expansion in the near future.

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[1] Geological Survey of Egypt : *Views of typical desert scenery in Egypt,* p. XI.
[2] *Topographical Atlas of Egypt,* 1 : 25.000, volume 4, sheets from 230-252.

REGION OF RICE AND CEREALS

It stretches in a narrow strip of land bordering the southern shores of lake Qarun. Here, rice is the main crop in rotation as it is shown from the following examples :

A) *Two-year rotation* [1] :

First year.	Winter period (shetwi)...	barley.
	Summer period (seifi)....	barley.
	Flood period (Nili)......	rice.
Second year. . .	Winter period (shetwi)...	bersim (clover).
	Summer period (seifi)....	bersim (clover)
	Flood period (Nili)......	rice.

B) *Three-year rotation :*

First year.	Winter period.........	bersim (clover) or barley
	Summer period........	cotton [2].
	Flood period..........	cotton.
Second year. . .	Winter period.........	barley.
	Summer period........	barley.
	Flood period..........	rice.
Third year	Winter period.........	bersim.
	Summer period........	bersim.
	Flood period..........	rice.

The three-year rotation appears in few places while the two-year rotation dominates, with rice as a major crop. This is due to the fact

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[1] In Egypt, agricultural year starts at November, and it is divided into three seasons :

A) Winter period : from November or October to May or June.
B) Summer period : from March or February to September or October.
C) Flood period : for July or August to November.

[2] Cotton is grown on almost all types of soil in the depression, with the exception of very light or sandy soils. The soil most suitable is a medium to heavy loam, which fortunately is the type most prevalent in the country.

that rice has a remarkable ability to withstand soil salinity [1]. Soils of this belt are poor and saline because they lie at such low levels as to be difficult of proper natural drainage. Moreover, every excess of water used for irrigating the higher lands beyond that actually required for the growth of the crop, injuriously effects these low lands.

However, effective drainage, prevention of leakage from canals if possible, and economy in the use of water, represent the main remedies to ameliorate and reclaim these soils. It would be also a desirable innovation if the government which provides irrigation works will also provide manures, and sell the water and the manures together because one is as essential as the other.

In this region, cotton is of minor importance due to the fact that, being long-rooted, is especially liable to root asphyxiation as a result of rise in the water-table.

On the other hand, rice, being the principal crop, has many varieties :

A) Sultany is the oldest and is more tolerant to salts than other kinds. Owing to its relatively low yield and slow growth (six months), it is losing some of its popularity with the farmer.

B) Fino is superior to Sultany in quality and yield, but its slow growth limits its popularity and acreage.

C) Japanese rice is noted for its rapid growth and large yield. Therefore, it is the most widely cultivated, in spite of the fact that it is inferior in quality to the previous two varieties. The best grades of this rice have been recently propagated by the Ministry of Agriculture [2].

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[1] Rice is more tolerant to salts in the soil than other crops, and it requires a great amount of water and so allows the washing process to be continued. During the first month, rice is watered every two to three days; second month, every four to six days; and third month, every six to eight days (Willcocks, *Egyptian Irrigation*, volume II, third edition, p. 775).

[2] The Permanent Council for the Development of National Production : *Agricultural Expansion* (in arabic), Cairo 1954, pp. 13-15.

The average yield per feddan has shown some improvement, rising from 0.76 dariba [1] in 1936 to 0.88 in 1952. This is resultant upon steady improvement of drainage and introduction of high yielding strains.

REGION OF COTTON AND CEREALS

It lies to the south of the previous belt and occupies most of the territory. Here the two-year and the three-year rotations are followed as shown from the coming examples :

A) *Two-year rotation :*

First year.	Winter period.	wheat, beans, barley or bersim.
	Summer period.	Wheat, beans, barley or bersim.
	Flood period.	Maize or rice.
Second year. . .	Winter period.	bersim
	Summer period.	cotton.
	Flood period	cotton.

B) *Three-year rotation :*

First year.	Winter period.	bersim or fallow.
	Summer period.	cotton.
	Flood period.	cotton.
Second year. . .	Winter period.	bersim.
	Summer period.	bersim.
	Flood period.	Maize or rice or fallow.
Third year. . . .	Winter period.	wheat.
	Summer period.	wheat.
	Flood period.	maize or rice or fallow.

Three interesting deductions can be drawn from the above examples :

1) Appearance of a fallow period in rotations. The fallow-time benefits soil texture and bacteriological activity through the deep cracks that appear before the advent of the next crop. When the soil dries up, bacteria decompose leaving enough extra nitrogen in the soil to provide next crops.

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[1] Dariba = 945 kilograms; a feddan = 4,200 square metres.

2) Agricultural seasons overlap, and all perennially irrigated lands are cultivated at least twice a year, with an interval of fallow between the crops of one season and those of another. In this way, the total area of crops exceeds that of the cultivated land.

3) Cotton is the most important crop owing to its price and to the large area over which it is cultivated [1]. It is followed in importance by maize, bersim [2], wheat, and rice.

COTTON

The area under cotton depends primarily on the financial profit gained by the farmer from cotton as compared with his potential profit from other crops. Therefore, it is likely to change with the rise and fall of cotton prices [3]. In some occasions, the Government has restricted the cotton area believing that such a policy would arrest the fall in cotton prices, increase the yield per acre, enlarge the area devoted to food products, and lead to the improvement of cotton varieties.

In recent years, the average yield per feddan has shown little progress, rising from 4.05 kantars [4] in 1948-1949 to 4.24 kantars in 1951-1952. Inadequate drainage and pests have been the main hindrances to the continued improvement of cotton yield in Fayum. Cotton pests remain the greatest enemy to cotton, and until these pests are brought fully under control, cotton yield will remain uncertain.

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[1] See appendix I, crops-areas in *the districts (Marakez) of the Fayum province*, 1939-1940 and 1949-1950.

[2] The lucrativeness of bersim (clover) is due to the fact that as many as five cuttings may be obtained in a season from one field.

[3] The cotton area in Fayum was : 1937-1938 : 100, 885 feddans; 1948-1949 : 78,811 feddans; 1951-1952 : 96,874 feddans (Ministry of Agriculture, Department of Statistics).

[4] Kantar = 141 kg.

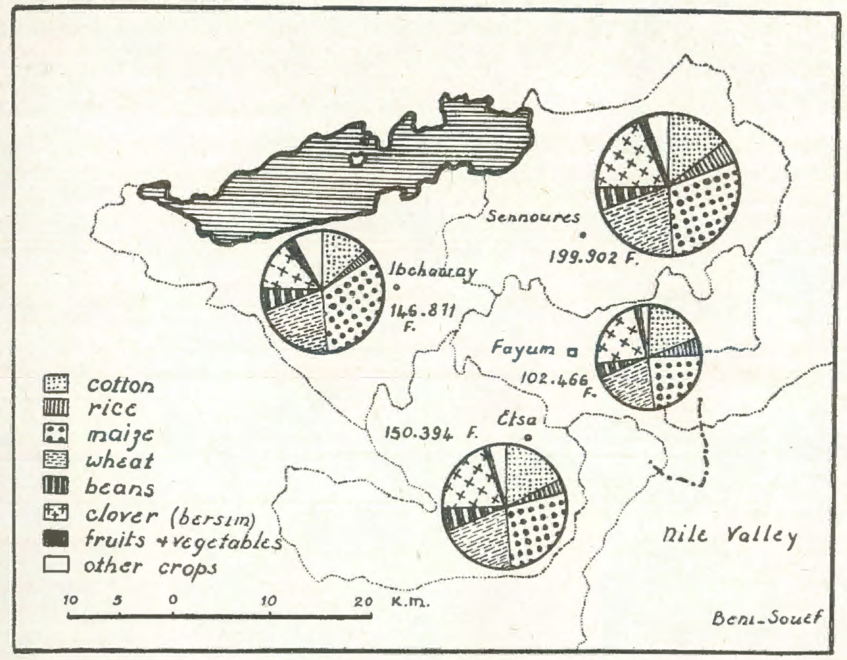

Fig. 1. — Crop Areas (feddans) 1939-1940.

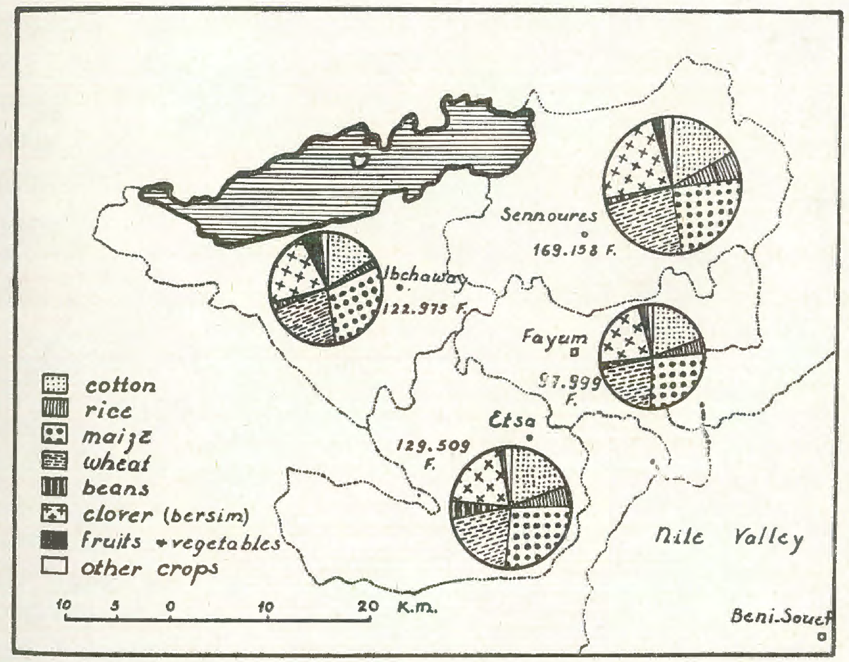

Fig. 2. — Crop Areas (feddans) 1949-1950.

Ashmuni and Zagora [1] are the main varieties in Fayum, and hold unchallenged sway in Middle Egypt. They are considered as medium varieties, and other strains are finer, longer, stronger and better in progressive degrees according to the particular variety, locality, and care in cultivation and handling. However, Ashmouni and Zagora are the only kinds which suit the desert climate of the depression. Their lower quality is compensated by their higher yield per feddan as compared with other varieties [2].

MAIZE

Regarding total acreage [3], production and importance as the staple food of the rural inhabitants, maize is by far the principal cereal in Fayum. However, there is a striking feature of maize acreage in recent years as it declines from 172,993 in 1939-1940 to 106,483 feddans in 1951-1952 in spite of the increase in summer water-supply and in population. This has resulted from the fact that the urban population in Egypt has increased in recent years more rapidly than the rural population and at the expense of the latter, as shown from the footnote table [4]. Therefore, there has been a steady increase in the acreage of wheat and rice as being more consumed in the towns than in the coun-

[1] Egyptian cotton varieties are classified into three main divisions :

A) long staple varieties (over $1^3/_8$"), as Sakel, Sakha 4, Maarad, Giza 7 and Malaki.

B) Long-medium varieties (over $1\frac{1}{2}$") as Wafir, and Giza 3.

C) Medium varieties (over $1^1/_8$") as Ashmuni and Zagora.

(HUSSEIN KAMEL SELIM, *Twenty years of Agricultural development in Egypt* (1919-1939), Cairo 1940, p. 121.

[2] H. K. SELIM, *op. cit.*, p. 119.

[3] See appendix I.

[4] The following table shows the rate of increase of the population of Egypt per cent per annum, and its distribution between the rural and the urban population.

Period	Rate for Egypt	Rural population	Urban population
1907-1917	1.4	1.23	2.15
1917-1927	1.1	0.83	3.0
1927-1937	1.2	1.19	2.05
1937-1947	1.8	1.0	3.0

MOHAMED IBRAHIM HASSAN, *Economic development in Egypt, Alexandria* 1953 (in arabic), p. 62.

try, while maize and beans have decreased as being the food of the rural population [1].

Concerning the yield per feddan, it has fluctuated between 5.22 ardebs [2] in 1948 and 5.46 in 1952. However, the experiments of the Ministry of Agriculture and Agricultural Society of Egypt [3] have shown that with improved methods of cultivation and manuring, and the choice of high-yielding varieties, as much as 16 ardebs could be obtained from one feddan [4].

WHEAT :

It is the most important winter crop in Fayum. The following table shows that wheat acreage depends on that of cotton, rising and falling in opposite proportion to it.

Crops	1948-1949	1951-1952
—	—	—
cotton.......	78,811 feddans	96,874 feddans
wheat........	111,702 feddans	108,003 feddans

This means that cotton is the premier crop in rotation, and any change in its acreage affects the area under winter crops and mainly wheat. It is evident that the continued improvement of irrigation and drainage, and frequent restrictions on cotton cultivation will greatly help to increase the area devoted to wheat.

The yield per feddan has shown good progress, rising from 4.62 ardebs in 1948 to 5.20 ardebs in 1952. This is due to propagation of scientific methods of cultivation and manuring, the control of the rust fungus, the introduction of better and high-yielding varieties, and supply of good seeds and fertilisers to small cultivators on credit.

Though this average yield is superior to that obtaining during the last war, much remains to be done in this direction as control of the trade in

[1] See appendix I.

[2] Ardeb = 140 kg.

[3] Agricultural Society of Egypt : *Technical paper* n° 15, «Experiments on maize», p. 71 (in arabic).

[4] H. K. SELIM, *op. cit.*, p. 146.

sowing-seeds by legislation, and the organisation of scientific research for the production of improved wheat varieties and their localisation in regions according to different soils [1].

REGION OF FRUITS AND VEGETABLES

Areas of fruits and vegetables are spotted on loamy soils near main towns and along some patches of high lying gravel and sand as shown from the map of agricultural land-use in the Fayum depression [2]. The acreage rose from 9893 feddans in 1939-1940 to 14380 feddans in 1949-1950 [3]. The area under vegetables represents about 30 % of the total acreage, and citrus trees cover about 50 % of the total fruit area.

The expansion of production in fruits and vegetables is mainly due to repeated restriction of cotton acreage and numerous measures of assistance rendered by the government to growers of fruits and vegetables. The popularity of citrus trees has been due to several reasons as : *a*) the suitability of climate and loamy soils to their cultivation, *b*) a long period taken by the fruit to mature (from October to May) facilitates its gradual absorption by the markets, *c*) it is rather easy to preserve citrus fruits in good condition either on or off the trees [4], *d*) their plentiful production and the elastic demands of the local market, *e*) the government assistance to the growers such as distribution of young trees at low prices, control of fruit diseases by fumigation and spraying, organisation

[1] The Permanent Council for the Development of National Production : *Agricultural expansion* (in arabic), pp. 8-10, Cairo 1954.

[2] Loamy soil consists of a friable mixture of clay and sand.

[3] See appendix I.

[4] (A) Y. Milad and A. Sawi, *Present position with regard to citrus fruits in Egypt, Report of the first Agricultural Congress,* volume II, pp. 217-227 (in arabic).

(B) B. Khair, *Contribution à l'étude du citron égyptien,* Strasbourg 1939.

(C) Ministry of Agriculture, reports of horticultural section on citrus fruits, 1943 and 1953 (in arabic).

of local and foreign markets, and the grant of generous bounties to exporters [1], *f*) the comparatively low incipient expenses of citrus-fruit orchards.

Production of fruits and vegetables will be increased in the near future, if the following solutions can be carried out :

1) The increase of local consumption by raising the purchasing power of the rural population through wage increases and a campaign directed towards improving its standard of living.

2) Greater care in the breeding and propagation of fruit trees and vegetables of good quality and high yield.

3) Localisation of each crop variety in districts which suit its growth, and avoidance of mixing varieties within each area. As a result, crop gathering, grading, packing and transport will be rendered easy and less expensive.

If these measures are adopted, Fayum province will be able to increase production of fruits and vegetables and accomplish the desired expansion in their acreage.

AREAS OF EXPANSION

Large areas around the southern shores of lake Qarun in the northwest and around marshes of Gharaq basin in the southwest, remain untilled and saturated with salt. Such waste lands are mainly due to the fact that they lie at such low levels as to be difficult of proper drainage. According to a detailed scheme studied by the Permanent Council for the Development of National Production, ten thousand feddans of these lands to the southwest of lake Qarun will be reclaimed by the end of 1956 [2]. A net of drains will be constructed and the lands will be

[1] *The National Production Council : Agricultural Expansion,* p. 23.

[2] Permanent Council for the Development of National Production : *Policy of water-supply* (in arabic), pp. 13-15, Cairo 1954.

washed and treated by amelioration crops as samar, deneba and rice. The reclamation of these areas will provide work for unemployed university graduates, and land for the landless peasantry.

Moreover, several parcels of high lying gravel and sand are scattered here and there amidist the cultivated areas. Such patches specially appear to the south of both Tamiya and Matar Tares, and in the Gharaq basin. Such lands have not yet been tilled due to lack of necessary water. This sandy soil can be ameliorated if it is mixed with clay from neighbouring areas and if water can reach it from near-by canals. However, according to the study of the National Production Council, the High Dam, when completed, it will be able to store about 120 billion cubic metres and insure water supply for the irrigation of a new area of 2 million acres to be reclaimed from the desert and in the Fayum depression [1]. Such sandy soils are excellent for the cultivation of vegetables and fruits with figs, vines and citrus fruits as the principal products.

CONCLUSION

The last two decades have witnessed many gains in the agricultural land use of the Fayum depression. The principal improvements may be summarised as follows :

1) Construction of drainage pumping stations in Gharaq basin, and many hundreds of miles of irrigation and drainage canals.

2) Intensified production of many commodities as cotton, cereals and fruits.

3) Improvement in the quality and quantity of many products, as shown from their yield per feddan.

However, the next twenty years will be more advantageous and will see more fruitful results if the coming proposals are put in consideration :

[1] Ibid., pp. 10-12.

1) Improvement of field drainage. It seems certain that until field drains are widely constructed to give every acre of perennially cultivated land its own direct access to lake Qarun, the problem of drainage cannot be considered as solved.

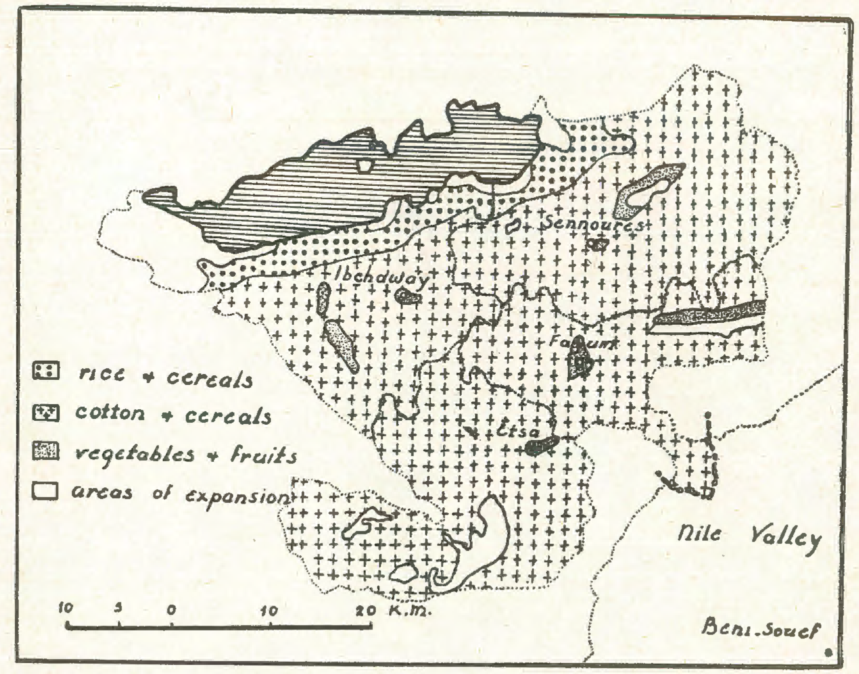

Fig. 3. — An agricultural Land-use map of the Fayum Depression.

2) Conservation of soil fertility. This can be assumed through a greater application of manures, improved drainage, scientific crop rotations, and allowance for occasional fallow periods.

This scheme, when executed, will be of the greatest agricultural importance to the country.

APPENDIX I

Crop areas in the districts (marakez) of the Fayum Province
1939-1940 *(in feddans)* [1]

Crops	Districts (Marakez)			
	Ibchaway	Sennouris	Fayum	Etsa
Cotton	20,351	28,369	19,510	26,107
Rice	2,459	9,974	5,138	5,065
Maize	48,573	58,572	24,381	41,467
Wheat	30,422	41,437	21,212	30,053
Beans	8,780	10,960	4,935	9,640
Clover (bersim)	21,170	37,400	22,819	29,757
Vegetables and fruits	3,816	2,991	1,567	1,519
Other crops	11,300	10,199	2,904	6,786
Total	146,871	199,902	102,466	150,394

Crop areas in the districts of the Fayum Province
1949-1950 *(in feddans)* [2]

Corps	Districts			
	Ibchaway	Sennouris	Fayum	Etsa
Cotton	19,499	27,429	19,146	25,816
Rice	2,506	11,148	3,911	6,486
Maize	35,670	41,929	26,337	34,745
Wheat	25,912	37,826	20,694	24,728
Beans	2,254	3,308	1,666	6,009
Clover	27,800	39,000	22,370	26,670
Vegetables and fruits	6,375	3,923	2,059	2,023
Other crops	2,959	4,595	1,816	3,031
Total	122,975	169,158	97,999	129,509

[1] *Annuaire statistique,* 1940-1941, p. 415, Cairo 1942.
[2] *Annuaire Statistique,* 1949-1950 and 1950-1951, p. 381, Cairo 1953.

THE HIGH DAM PROJECT

BY

DR. MOHAMED AHMED SELIM

I. INTRODUCTION

There can be no doubt that the problems which face our people have all emanated from one source and originated from one great problem, viz. the multiplication of the number of inhabitants. In the earlier part of the 19th century, i. e. in the days of the French Campaign, the population of Egypt did not exceed 2.5 million. In 1885 they were 7 million but they soon leapt to 10 million in 1897 and to 14 million in 1927. The increase went on steadily until nearly 16 million were recorded during the census of 1937, and more than 19 million in 1947. The population of Egypt today is almost 22 million. These figures indicate one main fact · the rapid and continuous growth of the population at a pace unknown in other countries.

It may be noted here that the per capita share of cultivable land has gradually decreased with the increase of population. In 1907 it was half a feddan per capita, but it dropped to ten kirats in 1927, and to seven kirats in 1947; and this last figure seems to hold good until today. In any case these figures go to show a serious drop in the per capita income in Egypt until it has dwindled far below the point of sufficiency.

And even this insignificant lot of 7 kirats per head will not be maintained unless we are quick in reclaiming no less than 2 million feddans before 1970, on the assumption that our population then will not exceed 26 million.

There can be no doubt, however, that to raise the standard of living among our people we should, side by side with the increase in the extent of cultivable land, endeavour to step up productivity. To this should be added the need for industrial advance which should be linked up with agricultural development for the consolidation of Egypt's economy.

To bring more land under the plough and at the same time increase the productivity of the land it is necessary to be able to provide adequate water supply whenever it is needed. Industrial development on the other hand necessitates the provision of cheap power energy.

Now a quick glance which we may cast at the « High Dam Project » will reveal that this project is capable of solving the two problems at one and the same time : it provides illimitable opportunity for a rapid increase in agricultural output and industrial production alike.

Briefly speaking, the project consists of the construction of a new dam accross the Nile—to the south of the Aswan Dam—which could permit storage at a level of 182 m. It may be remembered that the level of storage in the Aswan Dam at present is only 121 m. The capacity of the new dam will be 130,000 million cubic metres as against 5,000 million cubic metres, which is the capacity of the Aswan Dam.

The sharp fall of water from the new dam will be utilised moreover for the generation of electric energy amounting to more than five times the energy likely to be given in future by the Aswan Dam, and to more than ten times the electric energy consumed at present in the whole of Egypt—from Alexandria to Aswan.

The conception underlying the high dam Project :

A study of the records of the Nile discharges reveals their inconsistency. They vary greatly from one year to another. The volume of water required for the irrigation of the land under plough, at present, is 48,000 millions of cubic metres annually. The discharge of water which reaches the Aswan Dam may, however, be so low as to threaten the country with serious shortage in crops, as was the case in 1913-1914, when the discharge of the Nile was no more than 42,000 million cubic metres. In other years the discharge may be so great as to constitute a

real danger to the country, as happened in 1878-1879 when the discharge rose to 151,000 million cubic metres.

Then again while the requirements of agriculture in Egypt during the critical interval of summer (February to July) is estimated at 22,000 million cubic metres—including the quantities appropriated for storage at Aswan Dam which total 7,500 million cubic metres—we find the discharge of the river in 1878 reaching the alarming figure of 36,000 million during the summer interval. In 1913, on the other hand, it was only 7,000 million. These two paradoxical instances show the dangers which are likely to accrue from any scarcity of water-discharge on the one hand, and any over-excess on the other. And so it becomes extremely difficult to harmonize the water discharges of a fluctuating river with the reasonable demands of the country. A solution to this problem thus becomes incumbent on us, particularly as a result of the consolidation of the perennial system of irrigation and the increasing demand for water.

In fact any harmony between the constantly vibrating discharge on the one hand and the demands of the country on the other cannot possibly be secured through projects based on « annual storage » with which we have so far been familiar, as in the case of the Aswan and Gebel Awlia Dams, because the benefits of such dams are confined to the storage of part of the inundation water for use during the same « water year », when the Nile is very low in summer. Two important factors militate against further expansion in this type of storage. The first of these turns round the low discharges of water which very often take us by surprise. It is sufficient to review the behaviour of the river during the last fifty years to discover that there were certain years when it was difficult to fill up the dams of Aswan and Gebel Awlia. This irregularity tends to intensify the deficit in water during the following summer, partly owing to the insufficiency of the water stored in these dams and partly on account of depression in the natural discharge, because a poor inundation is usually followed by a comparatively low discharge of water. Thus it will be seen that if we were to depend on « annual storage » and were confronted, with our present expansion in agriculture, by a phenomenon similar to that of 1913 the catastrophe which would befall the

country would be likely in one year to do away with our agricultural wealth, and the damage would probably exceed the cost of all our projects for controlled irrigation.

The second factor which renders expansion in projects of « annual storage » unfavourable derives from the problem of Nile mud. Now flood waters from the Blue Nile and Atbara carry with them large quantities of alluvial mud. This mud precipitates in the basins of dams when the velocity of water is diminished during the process of storage. In view of this, it has been found necessary to delay the storage of water in the Aswan Dam until the drop in the level of the river reduces the quantity of mud hanging in the water.

Considerations of caution and care indeed make it uncumbent upon us to try to avoid any risk in respect of the basins of dams, and every measure should be taken to minimise the amount of silt deposited in their basins. The experience of other countries shows that many dams of a relatively small capacity had to be forsaken for others because they were blocked by river deposits.

At the Fourth Conference on Dams which was held in India in 1951, and at which I had the honour of representing my country, Egypt submitted a treatise on the storage of mud-laden water, as symbolised by the state of things in the Aswan Dam. Other countries too put their experience in this respect before the Conference. It was revealed that permanent storage of water dictates that dams should be so large as to allow enough room for the accumulation of mud.

Thus it will be seen that « annual storage » cannot solve the problem of river-control. Nor should we rely on ordinary dams—those used for annual storage—for meeting the requirements of future expansion in agriculture. Investigation has shown that the best medium, under the circumstances, is the system of « continuous storage » which aims at storing up surplus quantities during high floods, in order to increase the river's discharge in years of poor floods.

It is indeed significant that ancient Egypt should have been familiar with this kind of storage in the days of Joseph when surplus crops in years of plenty were stored for use in years of scarcity.

Naturally a system of continuous storage, such as has been alluded to,

requires a dam with a huge capacity, sufficient to permit the accumulation of surplus quantities of water during various successive years, and to ensure an adequate supply to cover any shortage resulting from low floods in other years, while at the same time allowing enough room for the precipitation of silt. Moreover, a dam of this kind should also ensure the maximum difference between the levels of water on either side of its walls, throughout the year, so that the maximum electric energy may be generated.

The idea underlying the « High Dam » is thus to ensure full and rapid utilisation of the Nile water. For one thing, it provides a huge reservoir which permits continuous storage of water. For another, it furnishes enough room to hold precipitating silt. It moreover wards off the dangers of exceptionally high floods and provides scope for the production of electric energy.

II. ECONOMIC ADVANTAGES OF THE PROJECT

1. It increases the land under plough to the extent of two million feddans including the transformation of existing irrigation basins in Upper Egypt to the perennial system.

2. It ensures successful agricultural expansion, even in the most scanty years, while irrigation water necessary for the various crops will be available in adequate quantities at propitious times. This will naturally help increase the agricultural output.

3. It ensures easy drainage for the lands of Upper Egypt, thus obviating the need for drainage stations whether those already in existence or those contemplated for the future on the Nile and on Behr Youssef.

4. It leads to a depression in the level of subterranean waters in the valley, in both Upper and Lower Egypt.

5. It wards off the dangers of the most exceptional Nile floods without the necessity of elevating Nile banks and strengthening embankments.

6. It ensures the appropriation of 700,000 feddans for the cultivation of rice no matter what the discharge of the river is.

7. It provides for the generation of electric energy amounting to 10,000 million kilowatts at a cost estimated at 6 milliemes per kilowatt

with the possibility of transmitting a good deal of the current to Cairo at a consumption price of no more than 2 milliemes per kilowatt, thereby opening up a wide vista for the rise of different industries.

8. It improves the economic aspect of the power station at Aswan.

9. It renders possible the expansion of the fertiliser factory, up to a capacity of 500,000 tons per annum.

10. It helps to maintain a steady difference in the level of the water on either side of the walls of the principal barrages, thereby helping to generate electricity.

11. It maintains adequate water supply in the river for easy navigation throughout the year.

12. It increases the national income by L. E. 355,000,000 every year in the final stages of the project.

13. It augments the State revenue by L. E. 23,000,000 in the year, in the final stages of the project.

14. It increases the value of reclaimed lands by approximately L. E. 300,000,000.

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It is worth noting here that apart from the economic advantages to which we have just referred, the construction of the «High Dam» will necessitate the drawing up of a new stable «water policy» for the control of the river waters in a manner which renders it possible to dispense with the erection of the main Nile Dam at the fourth cataract (Merwi) and the Wadi Rayyan Dam as well as the auxiliary canal which is contemplated in the Sedoud Region. While the advantages of the High Dam are greater (they ensure agricultural expansion to the extent of about 2,000,000 acres more) the expenses are less. Moreover, the «continuous» storage provided by the High Dam is too beneficial to be compared with the system of «annual» storage which was envisaged in the projects of Merwi and Wadi Rayyan. While annual storage leaves the country open to serious shortages in its water supply, continuous storage on the other hand is capable of ensuring the demands of agriculture even in years of exceptionally low floods.

III. SILT DEPOSITS IN THE BASIN OF THE HIGH DAM

It was quite natural that I should keep myself informed of comments and views expressed on the subject of the High Dam, ever since its construction was contemplated.

I can safely say that of all these comments I have not come across anything which might be regarded as a serious challenge save the remarks which turn round the precipitation of silt in the dam basin, which, it was claimed, would deprive the lands of Egypt of a refreshing and invigorating element. To those who fear this possibility I may submit the following data which I hope will rectify any false notion on this point and reassure them on the beneficial character of the project.

A. Quantities of Silt likely to precipitate in the Dam Basin.

The average quantity of suspended matter carried by Nile water is estimated at 110,000,000 tons every year, mostly during the flood season.

Research has shown the following relative composition of the constituents of suspended matter during the flood season.

Coarse sands	(0.2 — 2.0	millimetres) = Nil
Soft sands	(0.02 — 0.2	millimetres) = 30 %
Silt	(0.002 — 0.02	millimetres) = 40 %
Mud	(less than 0.0002	millimetres) = 30 %

In other words this suspended matter is composed of about 77,000,000 tons of silt and mud, the rest being soft sands.

On the other hand the velocity of water in the dam, however slow, will allow the carriage of 25 % of the silt and 90 % of the mud present in the water. In other words 41,000,000 tons will be carried away while the rest, some 69,000,000 tons, will be deposited in the dam basin. To this latter quantity are also added coarse sands which float near the bed and which are estimated at 21,000,000 tons. This means that the maximum quantity likely to be deposited in the dam basin is 90,000,000 tons or the equivalent of 60,000,000 cubic metres every year.

Thus if 30,000 million cubic metres, out of the total capacity of the dam, were left for precipitating silts they would be adequate for the purpose over a period of more than 500 years.

B. Dietetic Assets.

Research undertaken by the Ministry of Agriculture has evidenced the fact that only about 13,000,000 tons of silt reach Egypt annually and that most of this quantity is absorbed by irrigation basins. This absorption, however, will be reduced to 6,000,000 tons after the changeover from basin to perennial irrigation and to half this latter figure after the construction of the High Dam.

Now the dietetic elements in silt are estimated at L.E. 1,000,000 and this will accordingly be reduced to L.E. 460,000 after the transformation of basins to perennial irrigation. Half this amount will again be lost after the construction of the High Dam. This means a net loss of L.E. 230,000 which is nothing in view of the great benefits which the country will gain on the other hand. In fact this loss is even less than the amount expended every year for clearage purposes.

IV. SITE, CAPACITY AND DESIGN OF THE DAM

Site of the Dam.

In the light of the comprehensive studies and investigations undertaken by Consulting Experts of world wide fame, it was decided to construct the High Dam at Kilometre No. 6500 to the south of the Aswan Dam. This site was found to be the best and most suitable from every aspect. Apart from its constructive and economic advantages it will make it possible to secure adequate quantities of building material necessary for the construction of the dam from the neighbourhood.

Capacity of the Dam.

Since the main object of the high Dam is to ensure agricultural expansion, ward off high-flood dangers and generate electric energy, the capacity of the dam may be classified into the following sections :

Section I : Dead Storage, which implies the allowance made for the precipitation of mud. This has been estimated at 30,000 million cubic metres to correspond with a level of 147 m. before the dam. This section of storage is capable of meeting the accumulation of mud over a period of 500 years at the average rate of 60 million cubic metres every year.

Section II : Live Storage, which is reckoned at 70,000 million cubic metres, corresponding to a level of 147-175 m. This capacity ensures the discharge of 60,000 million cubic metres annually for purposes of agriculture.

Section III : for protection against high floods. The capacity allotted for this purpose is 30,000 million cubic metres. It is capable of warding off the menace of even the most dangerously high floods.

In other words the total capacity of the dam will be :

$$30 + 70 + 30 = 130{,}000 \text{ million cubic metres.}$$

It has been established that these contents of the dam can be maintained if the storing was kept up at a level of 182 m.

The average waste on the other hand has been estimated at 10,000 million cubic metres. The dam will throw its water back up to the Dal Cataracts, 150 kilometres in the Sudan territory.

Design of the Dam :

Is was decided that the dam should be constructed in such a manner that its walls can hold water up to a level of 182 above sea. The walls will be constructed from local building material. The upper surface of the dam will stand at a level of 196. The height of the dam itself will be about 110 metres and the length of its base across the river will be 1,300 metres.

The discharged water of the Nile will run through seven diversion tunnels on the eastern bank, each 16.5 metres in diameter and about 2,160 metres in length.

42,000,000 cubic metres of building material will be used in the construction of the dam, e. i. 17 times the size of the Great Pyramid. The cubic displacement of material for the erection of the diversion

tunnels on the eastern bank of the Nile will come to 8,000,000 cubic metres. The cubic displacement of material for the erection of tunnels on the western bank for electricity work will also be 9,000,000 cubic metres.

The water stored in front of the dam will be utilised for irrigation gradually, as from the fifth year beginning from the date of building up the dam.

V. COST AND FINANCE OF THE PROJECT

1. The construction of the High Dam including civil works related to the generation of electric energy and other works calculated to ward off the dangers of high floods and improve navigation will involve an outlay of L.E. 110,000,000. With the addition of another L.E. 10,000,000 for indemnity and compensation the total outlay of the construction of the dam will be L. E. 120,000,000 distributed in the following manner :

A. Storage works for agricultural expansion......	L. E.	68,000,000
B. Works related to precaution against high floods.	»	19,000,000
C. Civil works related to the power station in its final form..............................	»	31,000,000
D. Works related to the improvement of navigation	»	2,000,000
TOTAL...	L. E.	120,000,000

2. Irrigation water provided by the construction of the High Dam will be utilised for the reclamation of 2,000,000 feddans of which 1,400,000 feddans will be reclaimed during the first five years of the plan, involving an outlay of L. E. 49,000,000.

During that stage the construction of eight turbines will have been completed at a cost of L.E. 16,000,000. The outlay of electric wires and installations from Aswan to Cairo will cost L. E. 24,500,000.

3. Thus the total cost of the project during the first ten years will be L.E. 209,500,000, of which L. E. 71,500,000 will be devoted to the construction of the power station.

Estimating the production of electric energy at 4,300 million kilowatts annually, the cost of production will be 0.65 milliemes per kilowatt in Aswan. Reckoning that 3,300 million kilowatts of the generated power will be transmitted to Cairo annually, the price of electric consumption in Cairo will be 2.46 milliemes per electric unit.

4. During the second ten years 600,000 more feddans will have been reclaimed. These represent the remaining area scheduled for reclamation in the High Dam Project. The outlay in this case will be L. E. 32,000,000.

5. On this basis the total outlay of the construction of the High Dam and other works correlated to it will involve the expenditure of L. E. 241,500,000.

6. Should it be decided to proceed with the completion of the power station during the second ten years by increasing the number of its turbines to sixteen, the additional cost would be L.E. 24,000,000. This would bring the total outlay of the power station to L.E. 95,500,000. Reckoning the generation of electric energy at 6,300 million kilowatts per year, the cost of production would be 0.64 milliemes at Aswan. If 6,000 million kilowatts were transmitted annually to Cairo, the price of electric consumption there would be 2.02 milliemes per electric unit.

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Such is the project of the High Dam, and such are the advantages likely to accrue from it. The views of world famous experts convince us more and more of the soundness of the project and encourage us to proceed with its execution with vast strides. It is a project which will be foremost among the dams of the world as far as its construction, storage of water, and generation of electric energy are concerned.

ÉTUDES IRAKIENNES

(Première Série)

PAR

ÉTIENNE DE VAUMAS

I. GÉOGRAPHIE PHYSIQUE DE L'IRAK

Célèbre par les civilisations qui se sont épanouies sur son sol durant des millénaires, l'Irak est encore peu connu à l'heure actuelle sous l'angle géographique. Les noms d'Ur et de Suse, de Babylone et de Ninive, sont dans toutes les mémoires ; le souvenir des Sassanides et des Abbassides survit encore dans tout son éclat ; l'Irak moderne, lui, est trop souvent oublié dans sa personnalité et ses problèmes actuels. On sait tout au plus à son sujet, la plupart du temps, que c'est une plaine aux horizons illimités, que deux fleuves aux noms légendaires, le Tigre et l'Euphrate, le sillonnent de bout en bout, que la production du pétrole y est abondante. Ces quelques notations mises à part, il fait un peu figure d'inconnu.

Cette région est cependant en ce moment en plein développement. Touché plus tard que les autres pays arabes par la modernisation, il semble vouloir se lancer dans celle-ci avec une fougue qui, si elle se maintient lui permettra de rattraper rapidement bien des retards. Un effort d'équipement considérable est déjà entrepris qui doit lui permettre d'aménager les ressources très importantes dont il dispose, non seulement en pétrole, mais encore en terres et en eaux. Peu de contrées du globe ont devant elle de pareilles perspectives d'avenir.

Cette entreprise d'aménagement vaut la peine par conséquent d'être décrite. Avant de le faire, il a paru bon cependant de faire le bilan de

nos connaissances sur les conditions naturelles qu'elle est appelé à mettre en œuvre. Des services de toutes sortes ont déjà accumulé dans les domaines géologique, météorologique, hydrologique, quantité de données qui n'ont guère encore été jusqu'ici exploitées et qu'il importait de faire connaître tout d'abord.

C'est à cette synthèse, encore bien provisoire, que vise le présent article en attendant qu'un autre permette de décrire plus directement l'effort d'équipement qui se poursuit actuellement en Irak.

PREMIÈRE PARTIE

STRUCTURE ET RELIEF (fig. 1)

Dans son ensemble, la *structure* de l'Irak est d'une très grande simplicité [1].

Elle correspond à l'enfoncement vers l'Est et le Nord-Est du socle cristallin syro-arabe, partout recouvert d'une épaisse série de couches sédimentaires dont l'âge est de plus en plus récent au fur et à mesure qu'on avance vers le plateau iranien. Le Crétacé et même le Jurassique affleurent à proximité de la Jordanie. De manière générale cependant, c'est le Nummulitique et surtout le Miocène qui couvrent les immenses espaces du désert, de la Djéziré et des abords du Zagros.

Le socle syrien, fortement relevé à l'Ouest le long de la Méditerranée où les transgressions et les régressions se sont succédées depuis l'aurore des âges, semble avoir toujours été recouvert par la mer au contraire en Irak. Ce n'est qu'au Tertiaire, et même à la fin du Tertiaire, que la grande gouttière où coulent actuellement le Tigre et l'Euphrate, a été comblée et a commencé à émerger. Encore faut-il remarquer que

[1] Cette structure ne se comprend bien que replacée dans son contexte qui est celle du Proche-Orient tout entier. Nous nous permettons donc de renvoyer à notre mémoire : *La structure du Proche-Orient. Essai de synthèse. Bulletin de la société royale de Géographie d'Egypte,* XXIII, fasc. 3 et 4, p. 265-320, 13 fig., 11 planches photogr. hors-texte, 1950.

le colmatage de la Mésopotamie est encore plus récent et ne s'est opéré qu'au Quaternaire par l'alluvionnement intensif des deux fleuves. Il n'est d'ailleurs pas terminé ; la Mésopotamie est toujours à l'heure actuelle un pays mi-terrestre, mi-aquatique ; quant au golfe Persique qui en est le prolongement structural, il gît toujours sous une tranche d'eau qui pour être faible, n'en est pas moins réelle.

Cette structure ne se diversifie qu'au Nord-Est où se dresse la puissante chaîne du Zagros dont les sommets atteignent et dépassent même 3.000 mètres. Mal connue et peu cartographiée, cette montagne semble bien être formée par un axe cristallin que flanquent au Sud-Est de longs bourrelets anticlinaux reployant du matériel jurassique et surtout crétacé. L'ampleur et la régularité des plis évoquent le Jura dans sa partie interne, mais un Jura aux proportions beaucoup plus grandiose que celui qui longe la plaine suisse. A ses pieds, de petites rides se sont propagées dans le Tertiaire récent et montrent que les mouvements orogéniques qui ont donné naissance à cette chaîne, ont dû se poursuivre très tard.

A l'exception du Kurdistan [1], il n'y a donc pas à attendre grande diversité du *relief* irakien.

La montagne présente une belle morphologie jurassienne de monts et de vaux parallèles avec un réseau hydrographique où se reconnaissent de longues sections longitudinales raccordées par de courts tronçons qui franchissent les anticlinaux au fond de cluses profondes. Partout ailleurs, la monotonie est désespérante et demeure la grande règle.

Le désert ne présente un tout petit peu d'originalité que dans sa partie occidentale (région de Rutba). Les grandes rivières qui coulaient autrefois vers l'Euphrate y ont légèrement disséqué les couches crétacées et ont créé des entablements qui suivent leurs anciens lits que n'utilisent plus maintenant que les oued, gonflés temporairement par des

[1] La partie irakienne du Zagros est communément appelée Kurdistan. C'est dans cette acception du terme que l'on emploiera le mot ici. En réalité le Kurdistan, si l'on entend par ce mot le pays des Kurdes, déborde largement sur la Perse, la Turquie et même l'U. R. S. S.

pluies d'orage. Quelques buttes-témoins disséminées ici et là complètent ce paysage sans grandeur.

L'altitude est trop basse et la structure trop simple pour que cette dissection ait pu donner naissance en effet à des reliefs bien diversifiés. La seule exception à cette règle est la dépression d'el Gara où un dôme anticlinal, légèrement elliptique, a été évidé en boutonnière, donnant naissance à un bray typique de la même famille que ceux qui accidentent le Negeb palestinien [1].

La partie orientale du désert comme la Djéziré irakienne ne présentent même plus ce tout petit minimum de personnalité. Les ondulations du relief sont à peine perceptibles à l'œil, les anciens tracés des oued n'apparaissent presque pas non plus. Le regard ne trouve à s'accrocher au loin qu'à la ligne d'horizon d'une rigidité parfaite, ou plus près aux petits cailloux patinés qui parsèment la surface du sol. Quelques dépressions au dénivelé très peu accusé existent cependant ; le rôle de certaines d'entre elles s'avère devoir être très important pour l'avenir de l'Irak car c'est sur elles que l'on compte pour régulariser les régimes du Tigre et de l'Euphrate [2].

Quant à la Mésopotamie [3], toute entière remblayée par les alluvions quaternaires sur plus de 600 km. de longueur, elle se tient pour ainsi dire au ras de l'eau puisque Bagdad, situé à sa partie amont, n'est qu'à 34 m. d'altitude. C'est un monde où la terre dispute encore son existence à l'eau, où le Tigre et l'Euphrate divaguent sans fin et où les lacs et les marais occupent d'immenses superficies.

Malgré cette platitude, la Mésopotamie connaît des reliefs quelquefois imperceptibles à l'œil mais réels cependant : deltas intérieurs aux cônes

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(1) E. de Vaumas, *Le Negeb. Etude morphologique. Bulletin de la Société de Géographie d'Egypte,* XXVI, p. 119-163, 1 fig., 4 cartes et planches en dépliant hors texte, 1953.

(2) Dépressions du lac de Habbaniyé et de Bahr el Milh sur la rive droite de l'Euphrate, dépression de l'Ouadi Tharthar entre le Tigre et l'Euphrate.

(3) Le terme de Mésopotamie est employé ici pour désigner l'Irak méridional, c'est-à-dire la plaine de remblaiement quaternaire qui s'étend de Bagdad au golfe Persique. On l'oppose à celui de Djeziré (ou Irak du Nord) qui est un plateau de faible altitude, formé de sédiments tertiaires.

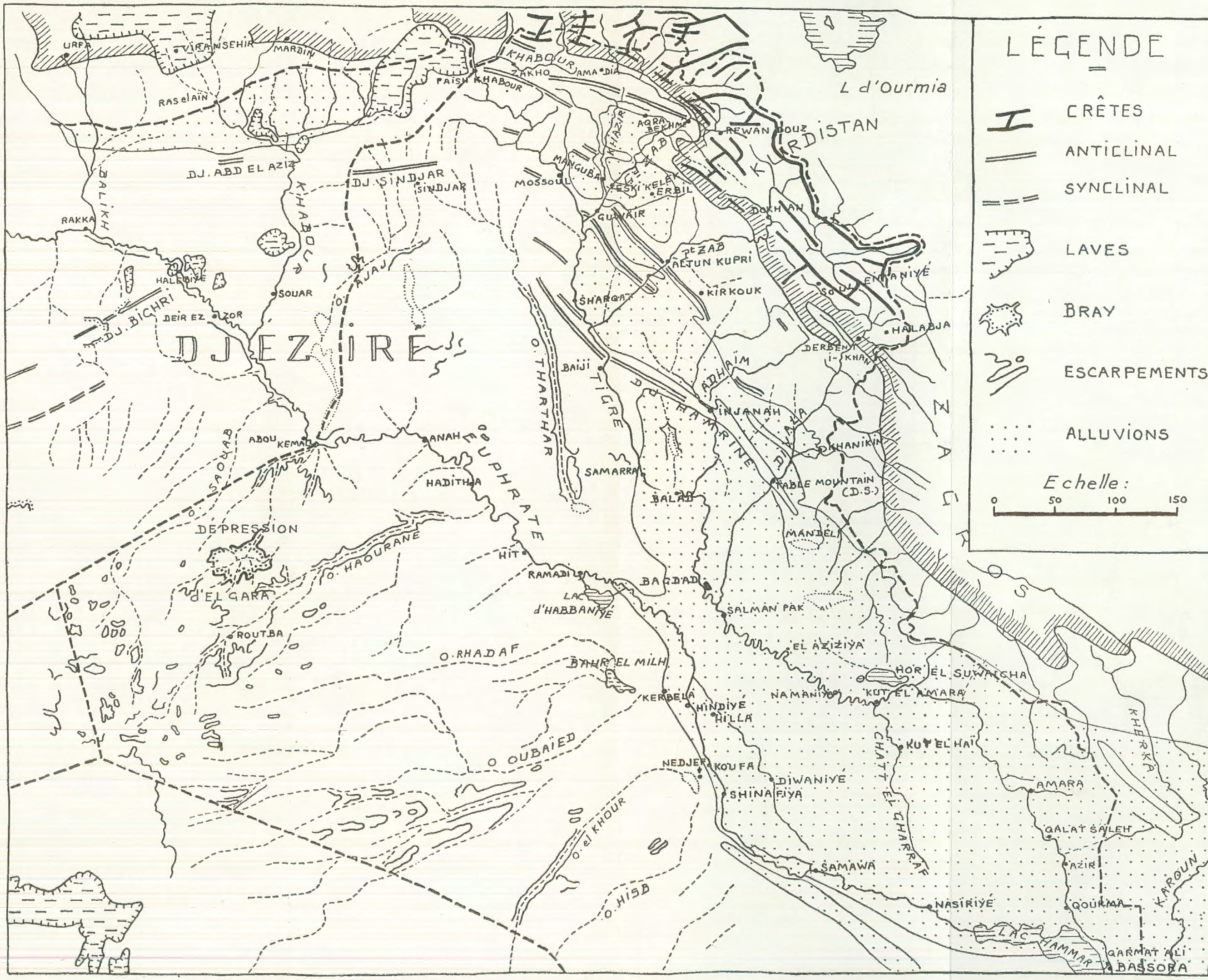

Fig. 1. — Structure et relief de l'Irak.

évasés et très aplatis, berges surélevées des fleuves et des canaux, lits correspondants à d'anciens tracés fluviaux, etc. . . Il serait du plus haut intérêt de connaître dans le détail toute cette morphologie comme de reconstituer l'histoire du remblaiement qui lui a donné naissance. Force est d'avouer que pour l'instant, tout cela nous échappe encore et que cette géographie et cette géologie demeurent entièrement à faire.

DEUXIÈME PARTIE : CLIMAT [1]

Le climat de l'Irak est, à l'exemple de sa structure et de son relief, relativement simple de telle sorte que ses caractéristiques essentielles se laissent déjà facilement dégager malgré le petit nombre de stations météorologiques.

1° *Pressions et Vents* [2].

Comme tout le Proche-Orient, *l'Irak est soumis à un système de hautes*

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[1] Les données en sont très dispersées. On les trouvera dans : Government of Iraq. Development Board. *Report on the development of the Tigris and Euphrates river systems.* Bagdad, 1952 — Government of Iraq. Directorate general of Irrigation. Ahmed Sousa, *The Euphrates* (1 vol. et 1 atlas), Bagdad, 1944 — Government of Iraq. Meteorological service. *Climatological atlas for Iraq.* Publ. n° 8. Bagdad, 1945.

Sur les pays voisins, on consultera : Ch. Combier, *La climatologie de la Syrie et du Liban. Revue de géographie physique et de géologie dynamique,* VI, p. 319-346, 1932 — Ch. Combier, *Aperçu sur les climats de la Syrie et du Liban avec carte au millionième des pluies et des vents.* Beyrouth, 1945 — Ch. Combier et I. Abd el Al, *Essai d'une formule de classification des climats du Levant. L'aridité et l'écoulement des pays du Moyen-Orient.* Publ. techn. et scientif. de l'Ecole franç. d'Ingénieurs de Beyrouth, n° 14. Beyrouth, 1948 — E. de Vaumas, *Le Liban. Etude de Géographie physique* (1 vol. de texte, 1 pochette de planches, 1 album de photographies). Thèse, Paris, 1954 (Bibliographie complète pour le Liban, partielle pour la Syrie) — D. Ashbel, *Bio-climatic atlas of Israël.* Jérusalem, 1948 — Government of Transjordan. M. G. Ionides, *Report on the water ressources of Transjordan and their development.* Londres, 1939.

[2] Données dans : Ahmed Sousa, *ouvr. cité,* tableaux 16, 17, 18, 19 (p. 25-29). Les observations s'étendent sur les années 1888-1918 et 1937-1941 pour Bagdad; 1908-1914 et 1923-1941 pour Mossoul; 1900-1918 et 1937-1941 pour Bassora.

pressions d'hiver et de basses pressions d'été. Les unes et les autres sont en dépendance des pressions atmosphériques qui existent en Asie à ces périodes de l'année.

Situé cependant en marge du continent asiatique, l'Irak ne connaît pas, surtout l'hiver, les pressions extrêmes qui se tiennent alors sur la Sibérie. Ce n'est que, durant 3 ou 4 mois seulement au plus, que Bagdad atteint une pression atmosphérique supérieure à la normale. Encore

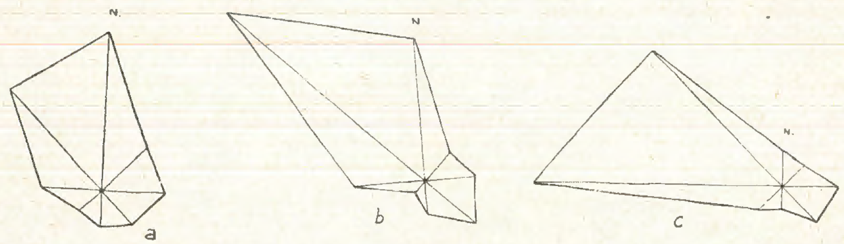

Fig. 2. — Roses des vents
a. Mossoul (1923-1924) *b.* Bagdad (1937-1941) *c.* Bassora (1937-1941).

s'en faut-il de bien peu (déc. : 1.019 millibars, janv. : 1.018, fév. : 1.017). Il en est de même à Bassora (nov. : 1.016, déc. : 1.019, janv. : 1.018, fév. : 1.016) et à Mossoul (nov. : 1.017, déc. : 1.020, janv. : 1.019, fév. : 1.016). D'une manière générale, la moyenne annuelle est au-dessous de la normale (Mossoul : 1.011 millibars, Bagdad : 1.010, Bassora : 1.009).

Le trait essentiel de l'Irak des fleuves est d'être en effet à toute époque de l'année un couloir de basses pressions entre les deux masses d'air plus lourd qui occupent le plateau iranien et le désert de Syrie, couloir qui se raccorde à la Méditerranée au Nord-Ouest et au golfe Persique au Sud-Est.

De cette position des centres atmosphériques, découle un *régime des vents* qui n'offre pas grande complication (fig. 2).

Aussi bien à Mossoul qu'à Bagdad et à Bassora, *les vents prédominants sont ceux du secteur Nord-Ouest. Ils soufflent toute l'année et totalisent jusqu'à 75 % des vents observés en été.* Ils sont en dépendance de la zone de basses pressions constantes de la Méditerranée orientale que l'Irak

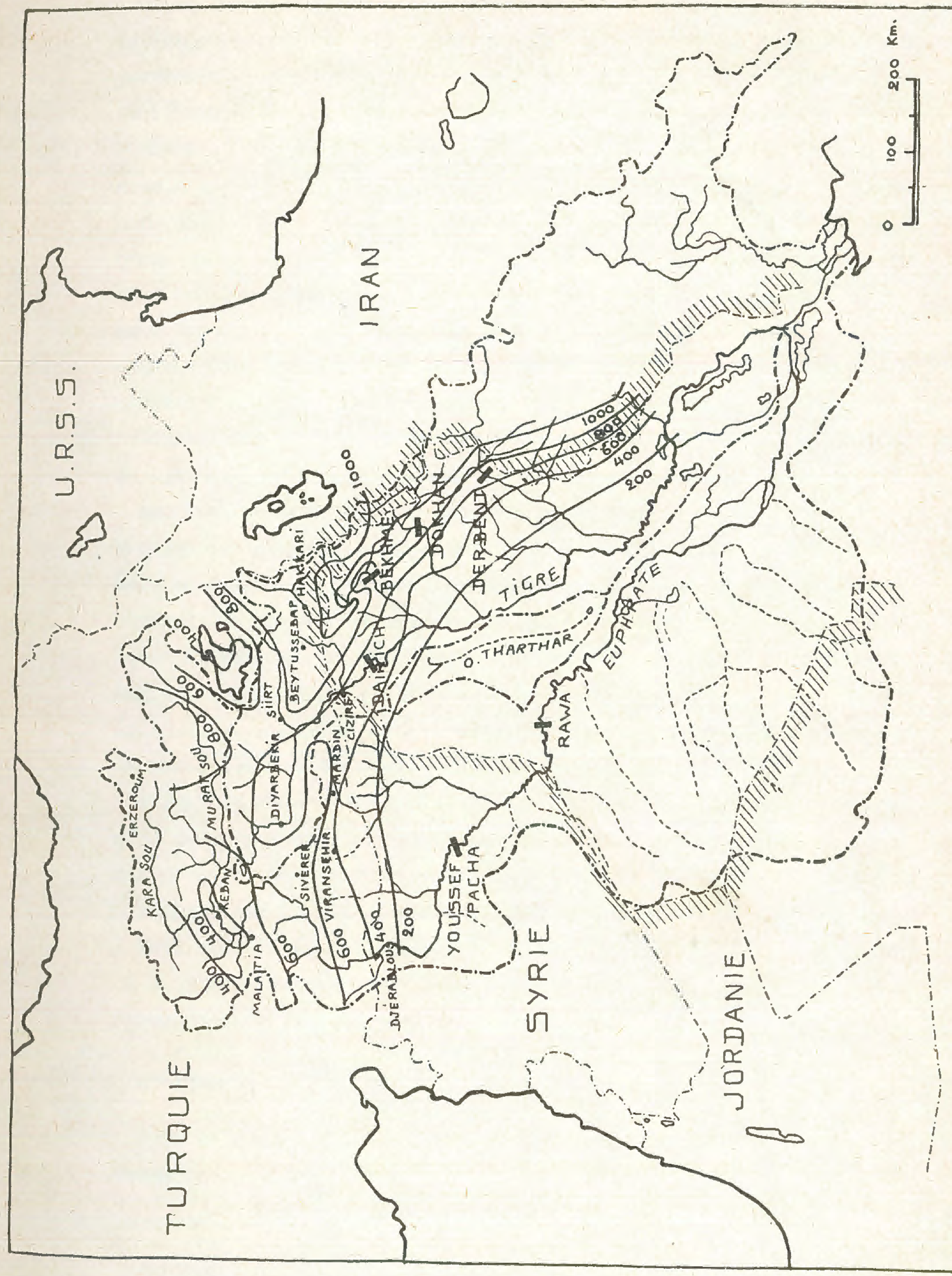

Fig. 3. — Bassins hydrographiques et courbes pluviométiques de l'Irak.
N. B. — Les gros traits noirs barrant les principaux fleuves indiquent l'emplacement des futurs barrages dont il sera question dans un article ultérieur.

prolonge vers l'Est et le Sud-Est. Cette zone exerce une attraction permanente sur les masses d'air qui proviennent de l'Atlantique ou de l'Europe. Ces vents de secteur Nord-Ouest sont appelés «Shamal».

A ceux-ci, s'ajoutent, mais seulement de novembre (d'octobre pour Bassora) à avril, des vents venant du secteur Sud-Est. Ils ont une fréquence beaucoup moins grande du fait qu'ils sont totalement inexistants au printemps et en été. Ils ne sont pas négligeables cependant et en janvier-avril, ils parviennent même parfois à égaler les vents du Nord-Ouest. Leur existence limitée à l'hiver donne à penser qu'ils sont en dépendance de la mousson dont ils ne seraient qu'un rameau divergent qui utiliserait le golfe Persique pour se propager vers le Nord-Ouest.

Quant aux vents des secteurs Sud-Ouest (Arabie) et Nord-Est (Zagros) ils sont très rares et n'exercent pas d'influence réelle.

Les mouvements de l'atmosphère se réduisent donc en Irak à un système assez simple comme le montrent les cartes mensuelles des *trajectoires cyclonales*[1]. Celles-ci viennent presque toutes de l'Ouest et forment un faisceau assez serré qui passe entre Deir ez Zor et Rutba. Après le méridien de ces deux localités (40° long.), elles s'infléchissent, soit vers le Nord-Est en direction du lac d'Ourmia, soit vers le Sud-Est pour rejoindre le golfe Persique. Quelques dépressions seulement viennent d'Arabie au cours de l'hiver (nov. à fév.).

L'Irak est donc à toute époque de l'année un pays où l'atmosphère n'est presque jamais en repos. Il arrive même parfois aux vents d'être dangereux lorsqu'ils précipitent au printemps le flot du Tigre et de l'Euphrate sur les digues qui sont alors crevées par la poussée des eaux.

Leur rôle le plus important toutefois n'est pas là du point de vue de la géographie physique mais dans l'influence qu'ils exercent sur la pluviosité d'où dépend toute la vie du pays.

2° *Pluviosité* (fig. 3 et 4).

Dans sa presque totalité, l'Irak reçoit moins de 200 mm. *de pluie annuellement.*

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[1] *Climatological Atlas for Iraq*, p. 83-90.

Cet isohyète qui, le long de la Méditerranée, se trouve aux confins septentrionaux du Negeb et même en Transjordanie aux environs de Pétra, se redresse alors plein Nord jusqu'aux abords d'Alep. A proximité de cette ville, il bifurque en direction de l'Est pour suivre la frontière

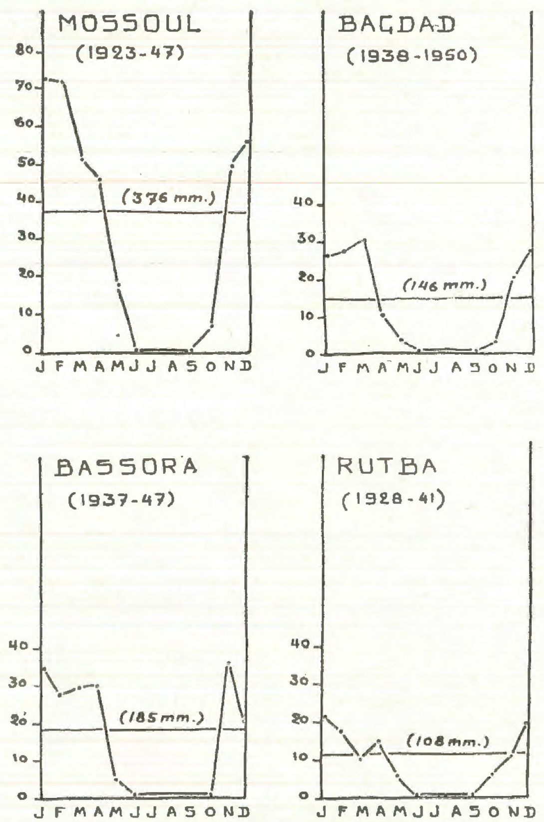

Fig. 4. — Courbes de pluviosité.

turco-syrienne, puis à hauteur du Bec de canard, s'infléchit à nouveau pour longer le Zagros auquel il reste grossièrement parallèle jusqu'au golfe Persique.

La Djéziré irakienne et la Mésopotamie sont des pays sans précipitations. Les chaînes côtières de la Méditerranée que les vents pluvieux venant de l'Ouest abordent de plein fouet, condensent la plus grande partie de l'humidité de l'air. A l'Est de ces montagnes, le désert est

trop peu accidenté pour que de nouvelles condensations puissent se produire, sinon de façon très occasionnelle. L'Irak serait donc voué à *la mort complète si le puissant bourrelet du Zagros ne le bordait et ne constituait un puissant écran pour le reste d'humidité que l'air méditerranéen conserve encore après la traversée du désert* (Tableau n° I) [1].

Dès la région des petites chaînes qui courent sous le Zagros et qui marquent d'ailleurs un relèvement général du relief, la pluviosité croit. Mossoul (223 m.) reçoit 420 mm.; Arbil (414 m.), 430 mm.; Kirkuk (331 m.) 405 mm.; Khanikin (201 m.) et Mandeli (137 m.) quoique situés beaucoup plus au Sud ont encore respectivement 340 et 316 mm. de pluie.

Dans l'Irak central, les isohyètes de 400 et 500 mm. correspondent à peu près aux courbes de niveau de 400 et 500 m. à partir desquelles la grande montagne commence à faire son apparition. Dans le Nord, les chiffres sont beaucoup plus forts puisque Zakho (422 m.) et Aqra (716 m.) reçoivent déjà 880 et 1.040 mm. Il existe donc bien un Irak non montagneux déjà relativement pluvieux ou même pluvieux. Il correspond au piedmont du Zagros et aux petites rides qui le parcourent. Du fait de l'amincissement progressif de celui-ci vers le Sud et surtout des différences des latitudes, la pluviosité y décroît assez rapidement, comme on vient de le voir, du Nord au Sud (Zakho : 880 mm. et Mandeli : 316 mm.); elle y est cependant toujours très nettement supérieure à celle de la Djéziré ou de la Mésopotamie.

Ce piedmont du Zagros ne suffirait cependant pas à alimenter l'Irak en eau si, derrière lui, ne se dressait la gigantesque barrière des montagnes kurdes et persanes où les précipitations dépassent 700 mm. Rewandouz (1.006 m.) dans le bassin supérieur du Grand Zab reçoit 910 mm., Souleïmaniyé (853 m.) dans celui du Petit Zab : 668 mm., Halabcha (724 m.) à l'amont de la Diyala : 772 mm. Ces chiffres, déjà honorables en eux-mêmes, laissent présager des tranches d'eau très supérieures, avoisinant 1.000 mm. et sans doute 1.500 mm., sur la

[1] La meilleure carte d'ensemble de la pluviosité du Proche-Orient (Turquie comprise) est celle de : D. Ashbel, *Rainfall Map of the Near East*. Jérusalem — Carte beaucoup plus sommaire dans : M. Clerget, *La Turquie*. Paris Colin, 1938.

TABLEAU N° I : PLUVIOMÉTRIE DE L'IRAK.

Stations	Années d'observation	Altitude (m.)	Pluie (mm.)
Amadiya	1936-39, 44-46, 48-49	1.236	770
* Amara	1936-39	9	212
* Ana	1936-39	—	138
Aqra	1936-39, 44-46, 48-49	716	1.040
Arbil	1936-38, 40, 44-45, 51	414	430
Bagdad	1938-50	34	140
Baiji	1936-44	143	176
Bassora	1900-18	2,4	176
* Diwaniya	1928-39	20	85
* Fao	1936-39	2	168
* Haditha	1934-39	—	142
Halabcha	1936-43, 46-51	724	772
* Hilla	1928-39	27	99
* Hindiya	1928-39	34	97
Iftichar	1936-46, 48-50	204	230
* Kerbela	1928-39	29	62
Khanikin	1936-50	201	340
Kirkuk	1936, 1939-51	331	405
Kut	1936-39	19	150
Mandeli	1936-39, 41-42, 46-51	137	316
Mossoul	1936-40, 42-50	223	420
* Qalat Sukhar	1936-39	13	107
Qarabeg	1936-41, 44, 48-49	119	208
* Qaraghan	1928-39	119	185
Rewanduz	1936-37, 39-43, 45-46	1.006	910
* Rutba	1929-39	615	121
Samara	1936-41	65	123
Samawa	1928-39	6	76
Sindjar	1936-39	—	495
Souleïmaniyé	1936-45	853	668
Table Mountain (D. S.)	1941-42, 47, 49-51	—	214
Tuz	1936-39, 42	220	205
* Ur	1928-39	4	73
Zakho	1936-51	422	880

N. B. — Les chiffres marqués d'un astérisque sont pris dans AHMED SOUSA, *ouvr. cité,* p. 32. Les autres, dans le *Report of Development Board* (La figure 3, tirée de celui-ci, est construite d'après ces derniers).

montagne proprement dite. Toutes les stations dont il vient d'être question sont en effet situées dans des vallées très abritées qui ne reçoivent par conséquent qu'une quantité d'eau très inférieure à celle des sommets.

Quant aux courbes mensuelles des pluies, elles sont de même type. Toutes montrent un maximum d'hiver et un minimum d'été, c'est-à-dire une répartition de l'année en deux périodes bien distinctes : une saison humide [1] plus ou moins longue selon la latitude : 6 mois à Mossoul, 5 mois à Bagdad et à Bassora, et une saison sèche durant laquelle juin, juillet, août, septembre et aussi octobre pour Bassora, ne reçoivent rigoureusement aucune goutte d'eau.

Ces courbes trahissent donc un régime de pluie de type méditerranéen. Elles montrent bien que les précipitations sont amenées par les dépressions cyclonales d'hiver qui, originaires de l'Atlantique, ont balayé la Méditerranée. La pluviométrie de l'Irak est semblable à celle de tout le Proche-Orient.

Pas complètement toutefois. L'examen attentif des courbes et surtout leur comparaison avec celles des stations situées à la même latitude en Syrie-Palestine, révèlent en Irak une légère complication du régime pluviométrique. Celle-ci n'est pas encore perceptible à Mossoul dont la courbe ressemble à celle d'Alep mais elle se détecte déjà très nettement à Bagdad où le maximum n'est plus en janvier ou en février avec forte diminution des pluies en mars comme c'est le cas sur les bords de la Méditerranée, mais durant ce même mois de mars; les pluies de décembre, janvier, février et mars représentant d'ailleurs des tranches d'eau sensiblement équivalentes. La courbe de Bassora manifeste le même phénomène d'une manière encore plus accentuée puisque l'étalement de la saison pluvieuse se fait sur six mois de l'année (nov. : 35 mm. 8 ; déc. : 21 mm. 2 ; janv. : 35 mm. 5 ; fév. : 27 mm. 4 ; mars : 29 mm. 5 ; avril : 30 mm. 5). Durant les six mois d'hiver, chaque mois reçoit une quantité d'eau à peu près équivalente.

[1] Plus de 20 mm. par mois.

La rapide montée des pluies en novembre-décembre, leur maximum en janvier-février, leur chute marquée et souvent brusque en mars-avril, si typiques des courbes pluviométriques syro-palestiniennes, n'existent donc plus en Irak que dans la région de Mossoul, c'est-à-dire au Nord. *Dès qu'on s'avance vers le Sud-Est et que l'on gagne Bagdad, une légère perturbation se fait jour dans les courbes qui traduit sans qu'on puisse en douter une autre source de précipitations.* Ce qu'on a dit plus haut du régime des vents permet de résoudre le problème. On a vu en effet qu'une part notable de ceux-ci soufflaient de novembre, et même d'octobre à Bassora, jusqu'à avril du secteur Sud-Est. Ces vents proviennent du golfe Persique et sont bien connus dans le pays pour relever la température et amener des nuages et souvent de la pluie. La courbe pluviométrique de Rutba, analogue à celle de Bagdad et de Bassora, montre que leur influence se fait sentir assez loin dans le désert.

Ces vents amènent cependant assez peu d'eau et ce n'est pas des précipitations qu'ils provoquent que vit l'Irak. Intéressantes à signaler sur un plan climatologique général, les pluies en provenance du golfe Persique n'exercent aucune influence sur les régimes de l'Euphrate et du Tigre :

Avec une très grande variabilité de ses précipitations, l'Irak s'affirme à nouveau comme franchement méditerranéen.

Entre 1887/1888 et 1918/1919, Bagdad a enregistré 439 mm. en 1889/1890 contre 51 mm. seulement en 1908/1909. De même, Bassora entre 1899/1900 et 1918/1919 a reçu 271 mm. en 1910/1911 et 53 mm. en 1916/1917.

A supposer même que les observations de ces périodes déjà anciennes n'aient pas toute la précision qu'on pourrait en attendre, elles dénotent des écarts trop considérables pour que ne s'y révèle pas un trait caractéristique de la climatologie irakienne. Les rapports entre le maximum et le minimum enregistrés sont de 8, 6 à 1 pour Bagdad et de 5 à 1 à Bassora; le maximum étant à Bagdad 3 fois plus fort et le minimum 3 fois plus faible que la normale (146 mm.); les mêmes cœfficients étant pour Bassora (185 mm.) de 1, 4 et 3, 5 [1].

[1] A Beyrouth (887 mm.), les rapports du maximum et du minimum à la

Cette variabilité est par conséquent si considérable qu'elle est non seulement de type méditerranéen (il n'y a pas d'années sans pluie) mais aussi de type désertique. Elle annonce déjà l'Arabie où les pluies ne tombent plus qu'occasionnellement.

La sécheresse est donc bien le trait marquant de l'Irak; la moitié de l'année s'écoule sans qu'aucune pluie ne tombe et, en hiver, les préci-

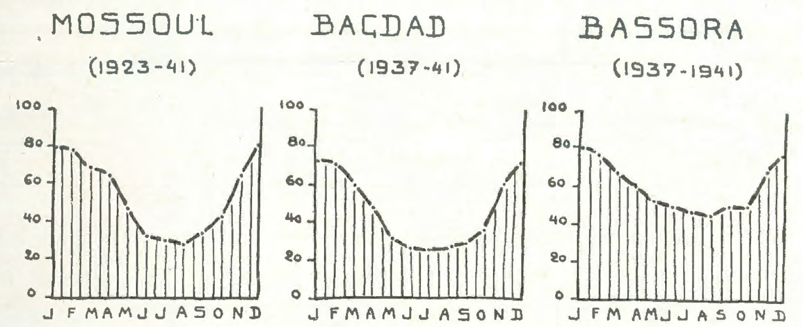

Fig. 5. — Courbes d'humidité relative.

pitations n'apportent en général qu'une très faible tranche d'eau, sujette de plus à de très grandes variations.

Les courbes d'humidité relative donnent de ce fait une dernière confirmation (fig. 5).

Elles présentent toutes un maximum d'hiver et un minimum d'été de telle sorte que les termes de saison humide et de saison sèche s'appliquent non seulement aux précipitations mais aussi à la teneur relative de l'air en humidité et à l'état du ciel. Par là, l'Irak se différencie des façades méditerranéennes des chaînes de Syrie-Palestine [1] où l'humidité relative est au contraire plus forte en été qu'en hiver et où le ciel est toujours encombré de

moyenne sont de 1,40 et 0,49; le rapport entre eux étant de 2,82 à 1. A Ksara (613 mm.), ces coefficients sont respectivement de : 1,44; 0,50; 2,34.

Cf. E. de Vaumas, *Le Liban,* p. 224.

[1] Voir : E. de Vaumas, *ouvr. cité,* p. 225 — Ch. Combier, *ouvr. cité,* dans lesquels on trouvera chiffres et figures.

nuages en été. Ce régime le rapproche au contraire de la Syrie intérieure et encore plus du désert où la courbe évolue comme la sienne : Mossoul est comparable à Deir ez Zor (80 en déc.-janv.; 27 cependant en août contre 35 à Deir), Bagdad (73 en déc.-janv., 26 en juill.) rappelle Damas (75 en déc.-janv., 38 en juill.). L'amplitude est donc beaucoup plus marquée qu'aux abords de la Méditerranée et même que dans le désert. Il n'est pas jusqu'à Bassora où la courbe d'humidité relative est pourtant moins creusée, qui ne soit comparable non pas aux stations de la côte libanaise mais bien à celle de Ksara dans la Bekaa.

Cette amplitude des courbes d'humidité relative suffit déjà à pronostiquer que le régime thermique de l'Irak doit manifester des contrastes encore plus marqués.

3° *Températures* (fig. 6).

Les températures de l'Irak dénotent un climat chaud. Pratiquement tout le pays, à l'exception du piedmont septentrional et de la montagne, a des moyennes annuelles égales ou supérieures à 20°.

L'influence de la latitude est déterminante comme le montre le tableau suivant.

Tableau N° II.

	Latitude	Température	Nombre de mois au-dessus de 20°
Mossoul	36° 19′	19° 3	6
Bagdad	33° 21′	22° 6	6
Diwaniya	31° 59′	23° 1	7
Bassora	30° 34′	24° 0	8

Par là, l'Irak diffère sensiblement de la Syrie et de la Palestine où l'altitude crée des contrastes puissants et où l'influence de la mer surtout adoucit fortement les moyennes jusqu'à une latitude assez basse. A ce point de vue, le Proche-Orient peut être partagé en deux. De la Méditerranée jusqu'au méridien du Khabour (41° long.), la carte des

températures ramenées au niveau de la mer montre que les isothermes ont une direction Sud-Ouest-Nord-Est; l'influence de la continentalité croissante d'Ouest en Est est aussi forte que celle de la latitude. A l'Est du méridien du Khabour au contraire, la latitude semble bien être le

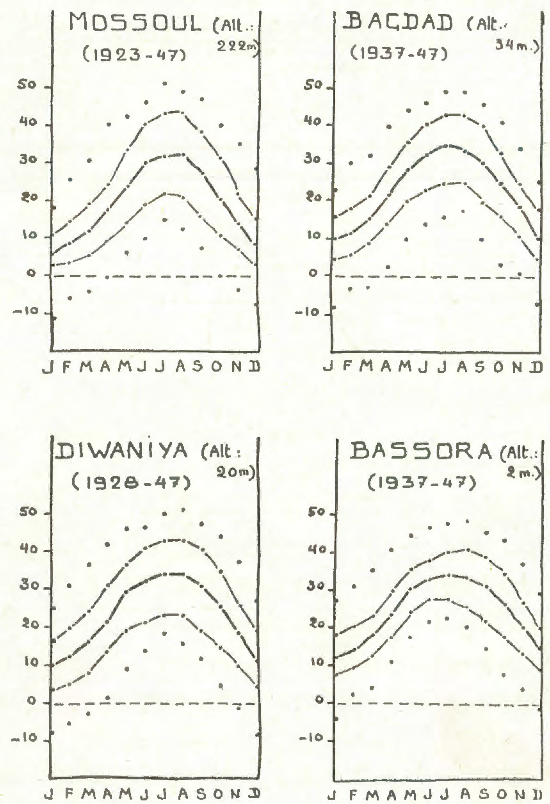

Fig. 6. — Courbes des températures.

seul facteur de l'augmentation des moyennes et les chiffres que l'on possède donnent à penser que les isothermes y ont un tracé Ouest-Est jusqu'aux abords du Zagros.

Les courbes des moyennes mensuelles des températures ont le même caractère schématique que celles des pluies. Les minima et les maxima sont, les premiers en janvier, les seconds en juillet, rarement en août comme à Mossoul. Les courbes des maxima et des minima moyens comme celles des

maxima et des minima absolus sont identiques et ne présentent pas ces brusques élévations de printemps que le Khamsin provoque dans celles de Syrie-Palestine.

La constatation la plus frappante néanmoins quand on compare ces courbes avec celles du Proche-Orient occidental est celle d'une *amplitude thermique très fortement accusée.*

TABLEAU N° III : AMPLITUDE THERMIQUE.

	Amplitude maximum		
	Entre les moyennes mensuelles	Entre Maxima et Minima moyens	Entre Maxima et Minima absolus
Mossoul	26° 1	41° 1	62° 2
Bagdad	24° 9	38° 7	57° 2
Diwaniya	24° 3	39° 8	59° 4
Bassora	21° 2	33° 3	53° 3

Les amplitudes sont partout considérables. Sur des latitudes à peu près semblables, Alexandrette a une amplitude de 17°8, Alep de 23°4, alors que Mossoul voit la distance entre le mois le plus chaud et le mois le plus froid s'écarter jusqu'à 26°1 ; de même Beyrouth ne fait que 14° d'écart, Ksara 18°9, Palmyre 23°4 tandis qu'à Bagdad celui-ci s'élève à 24°9.

Le caractère continental de l'Irak est donc puissamment affirmé par cette augmentation très forte de l'amplitude thermique par rapport à celle du Proche-Orient occidental. L'influence de la continentalité s'exerce surtout dans le sens Ouest-Est. Elle se fait sentir aussi quoique de manière moins marquée dans le sens Sud-Nord où les amplitudes vont croissantes de Bassora à Mossoul. Le rôle régulateur du golfe Persique est donc indéniable mais il ne va pas cependant jusqu'à masquer, ni même à atténuer très fortement l'aspect continental de l'Irak : Bagdad a une amplitude (24°9) de 10°9 plus forte que celle de Beyrouth (14°) tandis que cette même amplitude ne dépasse que de 3°7 celle de Bassora (21°2).

Une dernière remarque mérite d'être faite au sujet des températures pour noter que *le gel est rare en dehors du Kurdistan.* Tous les minima moyens connus, que ce soit dans le désert, en Djéziré, en Mésopotamie ou dans le piedmont du Zagros, sont au-dessus de 0°. Seuls les minima absolus sont susceptibles de provoquer la gelée, ces minima s'étant produits dans le passé sur un laps de temps de 6 mois de l'année à Mossoul, de 4 mois à Bagdad, de 2 mois à Bassora. L'altitude très faible de l'Irak semble responsable de cet état de chose qui n'existe certainement pas dans la partie occidentale du désert de Syrie, beaucoup plus haute surtout au Sud.

4° *Climats.*

L'Irak est infiniment moins riche en types de climat que la bordure méditerranéenne du Proche-Orient. Dans ce domaine comme dans celui de la structure et du relief, l'uniformité est la règle et il n'existe de contraste réel du point de vue climatique qu'entre l'Irak proprement dit et le Kurdistan.

Quoiqu'appartenant à la zone dite tempérée, c'est-à-dire celle où le mouvement de l'atmosphère se fait d'Ouest en Est, *le climat de l'Irak peut être défini en premier lieu comme un climat chaud.* A l'exception de la partie septentrionale où la moyenne annuelle tombe au-dessous de 20°, et encore de bien peu (Mossoul : 19°3), l'immense majorité de la plaine et du piedmont du Zagros est circonscrite par l'isotherme de 20°. Durant la moitié de l'année ou même durant plus longtemps encore, la moyenne mensuelle dépasse ce chiffre (6 mois à Mossoul, 7 et pratiquement 8 mois à Bagdad et à Bassora). L'Irak est un pays sans hiver sauf dans sa partie Nord où les moyennes tombent au-dessous de 10° durant 3 mois.

C'est aussi un climat de type méditerranéen avec maximum d'hiver et minimum d'été pour les pluies, maximum d'été et minimum d'hiver pour les températures. Mais c'est en même temps un climat méditerranéen *presque parvenu à sa limite de dégradation,* les pluies n'y atteignant plus 200 mm. dans l'ensemble, et où la continentalité a accusé brutalement les contrastes thermiques.

Il relève donc en même temps du type saharien tel que l'a défini Emm. de Martonne, «le plus sec et le plus extrême des climats chauds». A cette seule différence près qu'en Irak, les pluies quoique faibles et variables en quantité, sont régulière chaque année. En aucun pays du globe, ce type de climat ne monte aussi haut en latitude puisqu'il atteint ici et dépasse même le 36° de latitude qui est le parallèle de Gibraltar et de la Crète, et qu'il se combine déjà dans la région de Mossoul avec un début d'hiver.

L'extension de ce climat à la fois méditerranéen et saharien est très grande en Irak. Elle couvre le désert, la Djéziré et la Mésopotamie dans leur presque totalité.

Mais de même que le climat méditerranéen de type humide se dégradait en Syrie et en Palestine dans un type plus continental (type hellène) puis dans un type à la fois plus continental et plus sec (type syrien), une évolution analogue mais de sens inverse s'opère en Irak aux approches du Zagros. Le piedmont de cette montagne reçoit des pluies plus fortes que la plaine, son climat est de type syrien quoique les contrastes des températures soient beaucoup plus soulignés ici qu'en Syrie intérieure. Comme celle-ci cependant, c'est déjà une région de steppes où l'écoulement des eaux commence à se faire et où un début de vie sédentaire peut déjà s'organiser sans avoir besoin de recourir à l'irrigation.

L'extension de cette zone climatique est limitée. Elle correspond à une bande de terrain qui mesure une centaine de kilomètres de largeur dans le Nord de l'Irak (ancienne Assyrie) et qui va s'amenuisant vers le Sud-Est. Cette zone doit disparaître peu après la Diyala, c'est-à-dire à hauteur de Bagdad.

Quant au Kurdistan sur lequel on n'a que des données très insuffisantes, il doit se classer dans le climat méditerranéen de type montagnard à l'exemple du Liban quoiqu'avec des amplitudes thermiques vraisemblablement plus fortes que chez celui-ci.

TROISIÈME PARTIE : LES EAUX

Les données climatiques que l'on vient d'analyser laissent déjà prévoir que l'Irak est un pays sans eau. Ce ne sont pas les 176 mm. de pluie de Bassora, les 140 mm. de Bagdad ou même les 420 mm. de Mossoul qui sont susceptibles de donner naissance à de vrais organismes fluviaux.

La constatation maintenant bien prouvée pour la Syrie [1] que l'écoulement peut commencer dès 100 mm. de pluviosité ne change rien à l'affaire. Les causes invoquées : concentration des pluies sur une partie de l'année, leur répartition en averses de forte intensité, leur total saisonnier élevé et généralement supérieur à la plupart des pays de climat méditerranéen, les pentes vigoureuses, qui se sont révélées exactes en Syrie, peuvent l'être aussi (au moins les deux premières) pour l'Irak. Elles ne peuvent pas contrebalancer cependant de manière efficace les moyennes annuelles faibles ou même très faibles des pluies de Djéziré et de Mésopotamie, encore moins l'évaporation intense due aux moyennes thermiques très élevées.

En réalité, *l'Irak presque tout entier se trouve à l'intérieur de la zone aréïque délimitée par la courbe d'équiaridité de 15 (formule d'Emm. de Martonne).* Celle-ci après avoir longé la frontière syro-turque et turco-irakienne et avoir recoupé la grande boucle de l'Euphrate et les cours supérieurs du Balikh et du Khabour, s'infléchit au Nord-Est de Mossoul en direction du Sud-Est pour passer à peu près au milieu du piedmont du Zagros [2].

Seul le Kurdistan a un indice supérieur qui monte même jusqu'au chiffre de 25. Le reste du pays est au-dessous de 15 et même de 10 (cette

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[1] I. ABD-EL-AL, *Le Litani. Etude hydrologique.* Beyrouth, 1948, de même que l'ouvrage cité plus haut — S. MAZLOUM, *L'Afrine. Etude hydrologique. Revue de géographie physique et de géologie dynamique,* vol. XII, fasc. 1 et 2, 1939.

[2] Voir dans : CH. COMBIER et I. ABD-EL-AL, *ouvr. cité,* les cartes de l'indice d'aridité (formule d'Emm. de Martonne) pour l'année et pour janvier, avril, juillet, octobre, de même que les cartes (formule de L. Emberger) pour ces mêmes mois.

dernière courbe étant très proche de la précédente) ; le désert et la Mésopotamie au Sud du parallèle de Bagdad étant même au-dessous de 5.

L'Irak réaliserait donc un désert parfait si, comme l'Egypte, il n'était alimenté en eau par l'extérieur. Le Tigre et l'Euphrate lui sont aussi étrangers que le Nil l'est pour l'Afrique nord-orientale.

A cette différence près toutefois, et elle est capitale, que les sources d'alimentation de ces fleuves sont situées dans des directions diamétralement opposées. Les eaux du Nil proviennent de la zone intertropicale et elles ont déjà longuement cheminées avant d'arriver dans la zone aride tandis que l'Euphrate et le Tigre reçoivent les leurs de la zone tempérée et de massifs situés à proximité immédiate, surtout pour ce dernier.

Les régimes de ces deux fleuves ne peuvent donc être dans ces conditions que complètement différents de celui du Nil. Ils ont au contraire grande chance d'être très semblables l'un de l'autre.

I. LE TIGRE [1]

A la différence de l'Euphrate dont une grande partie du cours se trouve en Turquie, *le Tigre coule presque tout entier en Irak.* Formé par la réunion du Tigre proprement dit et du Botan-Sou qui se rejoignent à une centaine de kilomètres de la frontière, il a une orientation générale Nord-Ouest-Sud-Est, parallèle à celle du Zagros. De Diyarbékir à Garmat Ali (fig. 7), il ne mesure pas moins de 1.718 km., de telle sorte que sa longueur totale de la source jusqu'au Chatt el Arab doit être de l'ordre de 2.000 km.

Il ne reçoit aucun affluent sur sa gauche. Sur sa droite au contraire, toute une série de rivières originaires du Kurdistan et du Zagros l'ali-

[1] M. G. Ionides, *The Regime of the Rivers Euphrates and Tigris,* 278 pages, 79 figures, 128 tableaux. Londres, 1937 — F. F. Haigh, *Report on the control of the Rivers of Iraq and their utilization of their waters,* 190 p., tableaux et figures, Bagdad, 1951 — Fouad H. el Kholy, *Hydrology of river Tigris.* 181 p., 92 tableaux et fig. Bagdad, 1952. — *Report of the Development Board,* Bagdad, 1952.

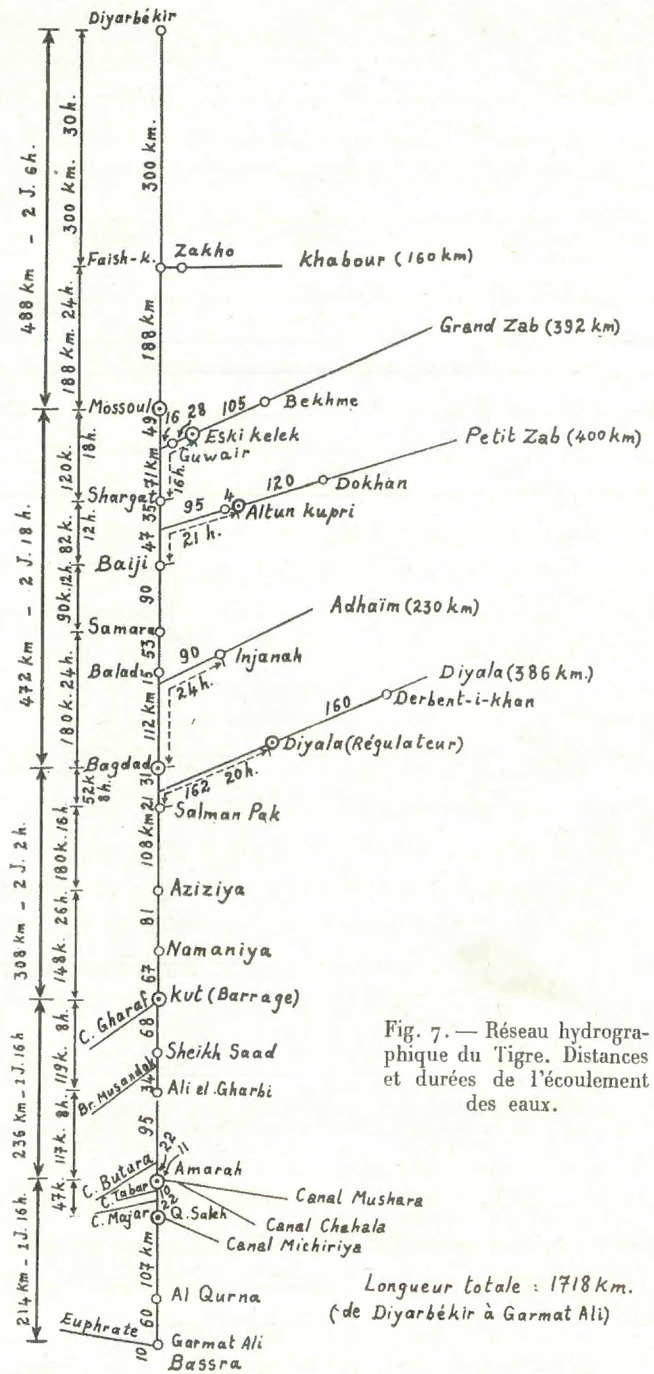


Fig. 7. — Réseau hydrographique du Tigre. Distances et durées de l'écoulement des eaux.

mentent et lui permettent de soutenir son débit à travers les plaines arides qu'ils traversent. Ce sont : le Khabour (160 km.)[1] qui est sans grande importance, le Grand Zab (392 km.), le Petit Zab (400 km.), l'Adhaïm (230 km.) et la Diyala (386 km.) qui sont presqu'exclusivement des rivières irakiennes. Plus au Sud, il reçoit encore la Kherkha, venue des montagnes de Perse et surtout le Karoun; celui-ci se jette dans le Chatt el Arab et se trouve par conséquent être moins un affluent du Tigre qu'une rivière indépendante.

Le fleuve est maintenant bien équipé en stations de jaugeage. Sur le Tigre lui-même, deux stations (Diyarbékir, et Gizré près de la frontière turco-syrienne existent depuis novembre 1945, deux autres fonctionnent aussi sur le Botan-Sou (Sinan et Billoris) depuis la fin de novembre 1945 ou le début de 1946, une station annexe est placée sur le Gazran à Beshiri un peu avant son confluent et se trouve être en service depuis la même date. Les résultats des mesures qui sont effectuées en ces différents points ne donnent malheureusement que des séries encore très courtes et ne sont d'ailleurs pas connues.

En Irak, les principales stations de jaugeage se trouvent à Mossoul, Bagdad, Kut et Amara. Elles sont doublées par d'autres moins importantes à Faish Khabour, Shargat, Baiji, Samara, Aziziya, Namaniya, Sheikh Saad, Ali Gharbi et al Qurna. Bien que les renseignements qu'elles donnent, soient d'intérêt inégal, elles permettent de suivre la vie du fleuve sur tout son parcours. Elles permettent aussi de préciser l'influence que les affluents du Tigre exercent sur lui au fur et à mesure que ceux-ci viennent s'y déverser.

Ces affluents n'ont ordinairement qu'une seule station de jaugeage importante, habituellement située dans le piedmont du Zagros : Zakho pour le Khabour, Eski Kelek pour le Grand Zab, Altun Kupri pour le Petit Zab, Injanah pour l'Adhaïm, « Discharge Site » ou « D. S. » (à la traversée du Dj. Hamrin appelé quelquefois Table Mountain) pour la Diyala. Ces stations donnent déjà une très bonne idée du régime des affluents du Tigre d'autant plus que leurs données peuvent être maintenant comparées à celles des stations moins importantes établies dans la montagne : Bekhme (Grand Zab), Dokhan (Petit Zab), Derbent-i-Khan (Diyala), points où s'édifient et doivent s'édifier de grands barrages qui font partie du plan d'équipement de l'Irak.

[1] A ne pas confondre avec le Khabour syrien, affluent de l'Euphrate.

D'une manière générale, ces stations sont en service depuis assez longtemps déjà pour que leurs séries de mesures échappent aux variations temporaires (voir les années d'observation sur le tableau n° VIII).

L'hydrographie du Tigre peut donc être étudiée à l'heure actuelle de manière très satisfaisante. M. Pardé[1] a eu le singulier mérite d'en dégager, voici déjà quinze ans, les grandes lignes et d'en présenter une belle synthèse à la suite du livre de M. G. Ionides. Cet exposé reste valable dans toutes ses parties essentielles; celui que nous présentons ici, ne vise qu'à le prolonger en fonction des éléments nouveaux que l'observation a apportés depuis.

1° Les facteurs du régime.

La climatologie ayant déjà fait l'objet de développements antérieurs aussi complets que possible, on s'étendra ici principalement sur l'influence que le relief exerce sur le régime du Tigre.

A. *Relief et nature du sol.*

Le relief joue un rôle considérable. C'est lui en effet qui commande très directement les précipitations qui donnent naissance au Tigre. Il est donc nécessaire de s'y arrêter tout en regrettant de ne pouvoir préciser plus l'influence que la nature du sol, encore mal connue, exerce sur l'écoulement.

1. Dessin, altitude et superficie du bassin hydrographique (fig. 1 et 3; Tableau IV).

[1] M. Pardé, *Les régimes du Tigre et de l'Euphrate d'après un livre anglais récent. Revue de géographie alpine,* tome XXVIII, fasc. IV, p. 511-565, 7 fig.

TABLEAU N° IV : BASSIN DU TIGRE (*Superficie en Km²*)
[d'après KHOLY, App. 88, page 173]

	Montagnes	Collines	Plaine	Désert de Syrie	Total	Alt. Max.
Tigre, à l'amont du confluent du Khabour	18.830	29.800	—	—	48.630	3.550
Khabour au confluent	4.605	1.663	—	—	6.268	—
Tigre, à Mossoul	23.435	31.463	—	—	54.898	—
Grand Zab, à Bekhme	16.630	—	—	—	16.630	—
Grand Zab, à Girdmamouk	18.420	800	—	—	19.220	—
Grand Zab, à Eski Kelek	18.554	1.909	—	—	20.463	—
Grand Zab, au confluent	19.470	7.003	—	—	26.473	4.168
Khazir, affl. du Grand Zab	860	2.355	—	—	3.215	—
Khazir, à Mangubah	860	2.075	—	—	2.935	—
Tigre, au confluent du Grand Zab (1)	—	—	—	—	82.731	—
Petit Zab, à Torba	10.940	600	—	—	11.540	—
Petit Zab, à Dokhan	10.940	750	—	—	11.690	—
Petit Zab, à Altun Kupri	11.670	3.952	—	—	15.622	—
Petit Zab, au confluent	11.670	10.580	—	—	22.250	3.200
Tigre au confluent du Petit Zab (1)	—	—	—	—	109.456	—
Tigre, à Fatha (près de Baiji)	54.575	55.662	—	—	110.237	—
Ouadi Tharthar	—	2.980	3.715	17.775	24.470	—
Ouadi Hauran	—	—	—	16.770	16.770	—
Tigre, à Samara (au débouché du canal de l'O. Th.) (2)	54.575	55.920	554	632	111.681	—
Adhaïm, à Injanah	—	9.686	154	—	9.840	—
Adhaïm, au confluent	—	9.815	1.173	—	10.988	1.500

(1) D'après le rapport du Development Board.
(2) N'inclut pas les bassins fermés de l'O. Tharthar et de l'O. Hauran.

Tigre, au confl. de l'Adhaïm (1)	—	—	—	—	131.754	—
Tigre, à Bagdad	54.575	65.735	13.317	632	134.259	—
Tangero (affl. de la Diyala)	2.050	550	—	—	2.600	—
Diyala, à Derbent-i-Khan	17.230	620	—	—	17.850	—
Diyala, au Dj. Hamrin (2)	19.810	9.868	—	—	29.678	—
Diyala, au confluent	19.810	9.868	2.218	—	31.896	2.000
Tigre, au confl. de la Diyala (3)	74.385	75.603	15.535	632	166.155	—
Karun, au confluent du Shatt el Arab	52.109	7.775	7.695	—	67.579	—
Khabour + Grand Zab + Petit Zab + Adhaïm + Diyala	—	—	—	—	97.875	—
Tigre (sans les affl. précéd.)	—	—	—	—	68.280	—

(1) D'après le rapport du Development Board.
(2) Point de jaugeage de la Diyala.
(3) Diyala comprise.

Le bassin hydrographique du Tigre se divise de manière quasi schématique en *deux parties presque totalement opposées tant du point du relief que de l'alimentation du fleuve : la plaine d'un côté, la montagne de l'autre.*

La plaine, au sens large du mot comprend les bas plateaux de Djéziré et le piedmont du Zagros de même que l'immense étendue alluviale et sans relief apparent de la Mésopotamie. Elle est difficile à délimiter en direction de l'Ouest où coule l'Euphrate, par suite de l'existence de bassins endoréïques dont le principal est celui de l'ouadi Tharthar. Elle est basse : Faish Khabour où le Tigre entre en Irak n'est qu'à 425 m. d'altitude bien que cette localité soit située à 1.000 km. à vol d'oiseau du golfe Persique. Moins de 200 km. à l'aval, Mossoul n'est plus qu'à 215 m. Quant à Bagdad, distant de la mer de 550 km., son altitude ne s'élève qu'à 30 m. Le piedmont du Zagros montre des élévations semblables (100 à 500 m.) qui ne sont pas suffisantes pour y voir une région distincte de la précédente. Enfin, et le point est capital, sous l'angle qui nous occupe, la plaine est pratiquement toute entière en dehors de la zone pluvieuse.

Contrastant avec elle à tous points de vue, la montagne incluse dans le bassin du Tigre se présente comme une immense façade qui, de la grande boucle de l'Euphrate où celui-ci commence, s'étire sur 600 km. si on exclut le bassin du Karoun, sur 900 km. si on compte ce dernier. Elle est orientée Ouest-Est dans sa partie septentrionale, puis Nord-Ouest-Sud-Est sur sa plus grande longueur. Elle mérite qu'on s'y attarde un peu.

De l'extrémité occidentale du bassin jusqu'à hauteur du lac de Van, c'est-à-dire, dans toute la région du Haut Tigre, la montagne est constituée par le Taurus arménien. En nul autre endroit, elle ne mérite mieux le nom de façade. Ici en effet, l'orographie est formée par un gigantesque escarpement cristallin dont l'altitude atteint de 2.000 à 2.500 m. pour culminer à 3.550 m. Les rivières en dévalent directement et sont collectées au pied des monts par une artère longitudinale : le Haut Tigre et le Botan-Sou. Aucune d'entre elles, tant l'érosion est encore jeune, n'a mordu sur le plateau intérieur. Le réseau hydrographique se présente comme un rateau aux dents à peu près égales et dont le manche serait constitué par le Tigre depuis son confluent avec le Botan-Sou jusqu'à son entrée en Irak. Dans son ensemble, le bassin (48.630 km²) est montagneux pour les deux cinquièmes (18.830 km² en montagne contre 29.800 km² en plaine). Il s'étend tout entier dans la zone pluvieuse.

A hauteur de Zakho, la façade tourne au Sud-Est et augmente d'altitude. Celle-ci est presque toujours supérieure à 2.500 m. et culmine au-dessus de 4.000 m. En même temps, le noyau cristallin se voit flanc gardé désormais sur son côté Sud-Ouest par des chaînes de type jurassien. Ici encore, le réseau hydrographique ne dépasse pas le faîte sauf au Nord où le Grand Zab a poussé sa tête sur le plateau iranien et en est parvenu à drainer la haute chaîne montagneuse qui sépare le lac de Van et le lac d'Ourmia. Son tracé montre des tronçons transversaux comme c'était déjà le cas pour le Haut Tigre mais aussi des directions longitudinales dues aux synclinaux. *Le bassin du Grand Zab* (26.473 km²) est essentiellement montagneux et ne comporte que 7.003 km² dans le piedmont du Zagros.

Le bassin du Petit Zab est un peu plus petit (22.250 km²) et fait la part plus large à cette dernière région (10.580 km²). Le Zagros y conserve la même orientation et la même structure que dans le bassin de son congénère mais les altitudes y diminuent de manière notable ; elles ne dépassent 3.000 m. que très localement dans sa partie Nord-Ouest et ne se tiennent plus qu'à 1.500-2.000 m. dans sa partie Sud-Est. Toutefois l'érosion régressive est encore forte car le Petit Zab à l'exemple de son voisin plus puissant a lui aussi poussé sa tête au delà du faîte jusque sur le plateau iranien.

L'Adhaïm n'est qu'une rivière très secondaire dont le bassin (10.988 km²) ne fait que s'appuyer sur la première chaîne montagneuse sans mordre sur elle. Il ne faudra donc pas s'étonner de ne lui trouver qu'une très faible alimentation.

La Diyala au contraire descend du faite lui-même. Son bassin très étendu (31.896 km²) est situé pour près des deux tiers dans la montagne dont l'altitude (2.000 m. ; parfois 2.500 m.) rappelle celle du bassin du Petit Zab. Elle ne reçoit que très peu d'affluents sur sa droite tandis que sur sa gauche lui arrive toute une série de rivières installées dans les synclinaux du Poucht-i-Koh qui dessine une vaste protubérance vers l'Irak.

La Kharkha en est pour ainsi dire symétrique. Elle draine la partie Sud-Est du Pouch-i-Koh comme la Diyala écoulait les eaux de la partie Nord-Ouest. L'altitude du bassin s'y renforce cependant (2.500 m., parfois 3.000 m.).

Dans le bassin du Karoun, les tracés longitudinaux se multiplient et les altitudes de la montagne affirment puissamment le relèvement du relief (3.000 m. et parfois 3.500 m.) déjà constatable dans le bassin de la Kerkha. La superficie drainée est aussi beaucoup plus considérable (67.579 km² dont 52.109 km² en montagne). Malheureusement les données hydrologiques sur cette rivière sont peu abondantes et il n'en sera que peu question par la suite.

Au total, le bassin hydrographique du Tigre est peu compliqué. C'est une série de compartiments juxtaposés qui divisent le Taurus arménien et le Zagros. Dans sa partie vraiment vivante, il s'étend sur 166.155 km² dont près de la moitié se trouve en montagne (74.385 km²) et près d'une autre moitié dans le piedmont du Zagros (75.603 km²) ; ce n'est

que sur une surface très limitée qu'il s'étend dans la plaine (15.535 km²) et dans le désert de Syrie (632 km²).

Le réseau hydrographique comprend essentiellement deux parties bien différentes : les rivières nourricières d'une part (Haut Tigre et Botan Sou, Khabour, Grand Zab, Petit Zab, Adhaïm, Diyala, Kherkha, Karoun) qui drainent la façade montagneuse; *une grande artère d'évacuation d'autre part* (le Tigre de Faish Khabour à son confluent avec l'Euphrate).

L'alimentation des rivières nourricières est fonction de l'altitude et de l'orientation de l'arc montagneux, de la superficie de leur bassin et de la proportion de celle-ci située en montagne, de la latitude enfin.

Nul doute que la configuration de l'arc montagneux du Taurus arménien et du Zagros ne soit admirablement dessinée pour nourrir un grand fleuve. Elle forme une muraille qui condense l'humidité venue de l'Ouest et s'apparente par là aux autres façades humides si caractéristiques de l'Asie sud-occidentale (littoral de Samsoun et de Trébizonde au pied des chaînes du Pont, rivage du Ghilan et du Mazandéran le long de l'escarpement de l'Elbourz qui fait face à la Caspienne, massifs côtiers méditerranéens de l'Amanus, du Dj. Ansarié, du Liban et de Palestine). Le cul de sac qu'elle forme dans la région de Mossoul semble bien être un lieu de pluviosité maximum.

Et ceci d'autant plus que l'arc montagneux y atteint ses plus grandes altitudes entre celles plus basses du Taurus arménien et du Pouch-i-Koh. Certains massifs sont même si élevés que tout laisse prévoir que la neige joue un rôle important dans les précipitations atmosphériques.

La latitude intervient cependant aussi et ce n'est que par l'étendue de leur bassin que la Diyala et le Karoun paraissent sauver leurs débits qui autrement seraient sans doute beaucoup plus faible.

Sur la nature du sol, les renseignements sont vagues. L'extension des calcaires dans le Zagros donnent à penser que les phénomènes karstiques, y sont répandus. Rien cependant dans l'hydrologie du Tigre et de ses affluents ne permet de conclure qu'ils jouent un rôle comparable à celui qu'ils exercent dans le régime de l'Oronte, du Litani et des rivières syro-libano-palestiniennes [1].

[1] Voir les travaux de S. Mazloum, I. Abd-el-Al et J. Weulersse (Références dans E. de Vaumas, *Le Liban*).

La végétation très clairsemée, même en montagne, ne semble pas non plus avoir un rôle important dans l'écoulement des eaux. Les pentes sont d'ailleurs si fortes sur les rivières nourricières que le rôle de la nature du sol et de la végétation ne peut en être qu'oblitéré.

2. Les Pentes.

Aucun des affluents du Tigre ne dépasse 400 km. Tous prennent leur source à plusieurs milliers de mètres. *Ils ne peuvent donc avoir qu'une allure torrentielle* que la traversée du piedmont n'a pas le temps d'atténuer de manière notable. Les pentes par conséquent sont très favorables à un écoulement rapide pour l'ensemble des rivières nourricières du Tigre.

Tableau N° V : Distances et Pentes du Tigre.

	Distances de l'aval à l'amont	Distances (Km.) de l'amont à l'aval	Niveau moyen (m.)		Pente ($^{cm}/_{Km}$)
			Hautes eaux	Basses eaux	
Faish-Khabour	1.516	0	—	—	100
Mossoul	1.328	188	217,40	212,80	
Shargat	1.208	308	151,00	147,00	56
Fatha	1.136	380	113,10	108,60	53
Baiji	1.126	390	106,90	103,40	
Samara	1.016	500	60,70	55,40	50
Balad	972	544	43,60	39,30	
Khan-al-Judaida	894	622	39,70	—	6,9
Bagdad	856	660	34,60	28,50	
Salman-Pak	804	712	31,00	23,80	—
Aziziya	712	804	—	—	6,7
Kut	548	968	18,50	11,80	
Amara	302	1.214	7,70	5,40	3,4
Limite de l'effet de la marée	196	1.320	4,50	2,90	
Bassora	100	1.416	—	—	1,3
Fao	0	1.516	2,00	—	—

Il n'en est plus de même pour l'artère de drainage elle-même. Ou du moins pas partout (figure 8 et tableau V).

En Djéziré, c'est-à-dire jusqu'un peu au Sud de Balad, le Tigre coule légèrement encaissé dans le plateau et les berges peuvent atteindre une dizaine de mètres de hauteur.

La pente est de 100 cm./km. (1/1.000ᵉ) de Faish Khabour à Mossoul (188 km.), ce qui représente un profil encore assez incliné.

Elle tombe à 56 cm./km. (1/1.800ᵉ) entre Mossoul et Shargat (120 km.), situé après le confluent du Grand Zab, puis à 53 cm./km. (1/1.900ᵉ) entre Shargat et Baiji (82 km.) qui se trouve après le confluent du Petit Zab. Elle est encore de 50 cm./km. (1/2.000ᵉ) entre Baiji et Balad (154 km.) où le Tigre entre dans la plaine alluviale de Mésopotamie.

La partie de son cours où le Tigre reçoit ses deux affluents principaux a des pentes comparables « à celles, encore fortes, de la Loire entre l'Allier et Orléans, de la Garonne entre le confluent du Tarn et Agen, du Rhône entre Lyon et Tournon »[1]. Ces pentes sont donc très favorables à une évacuation rapide des eaux, trop favorables du fait que la période des crues est à peu près la même pour le Haut Tigre, le Grand Zab et le Petit Zab et que la masse de leurs flots accumulés se précipite d'un seul coup sur la Mésopotamie et notamment sur Bagdad. La Djéziré manque d'une région de retenue d'où les eaux puissent ne s'écouler que progressivement. La création de cette région régulatrice est un des grands problèmes de l'équipement actuel de l'Irak; celui-ci est d'ailleurs en passe d'être résolu comme on le verra dans un article ultérieur.

Après Samara, après Balad plus exactement, la pente du Tigre s'effondre brusquement alors que le fleuve est encore à 972 km. du golfe Persique. L'altitude du fleuve n'est plus que d'une cinquantaine de mètres. Les pentes sont de plus en plus faibles jusqu'à en devenir dérisoires :

6,9 cm./km. de Balad à Bagdad (116 km.) : 1/14.500ᵉ.
6,7 cm./km. de Bagdad à Kut (308 km.) : 1/15.000ᵉ.
3,4 cm./km. de Kut à Amara (116 km.) : 1/29,000ᵉ.
1,3 cm./km. d'Amara à la mer (302 km.) : 1/76.000ᵉ.

[1] M. Pardé, *ouvr. cité,* p. 522.

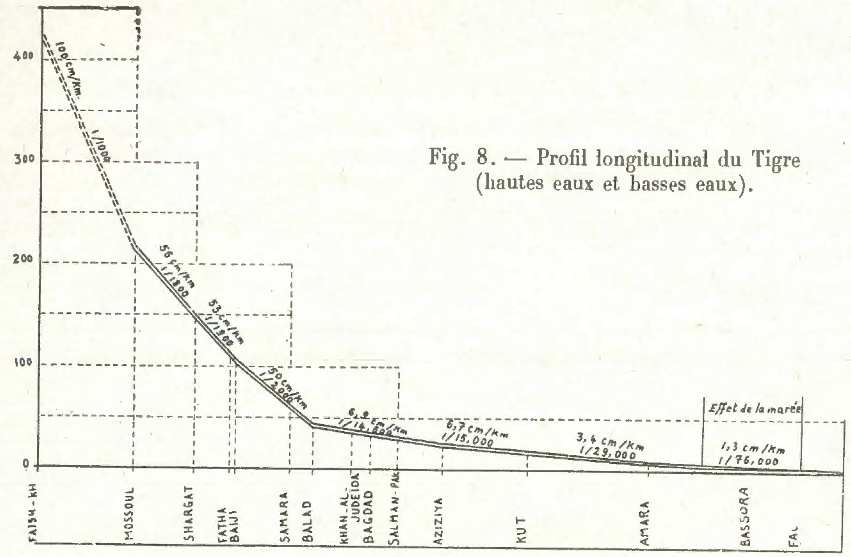


Fig. 8. — Profil longitudinal du Tigre (hautes eaux et basses eaux).

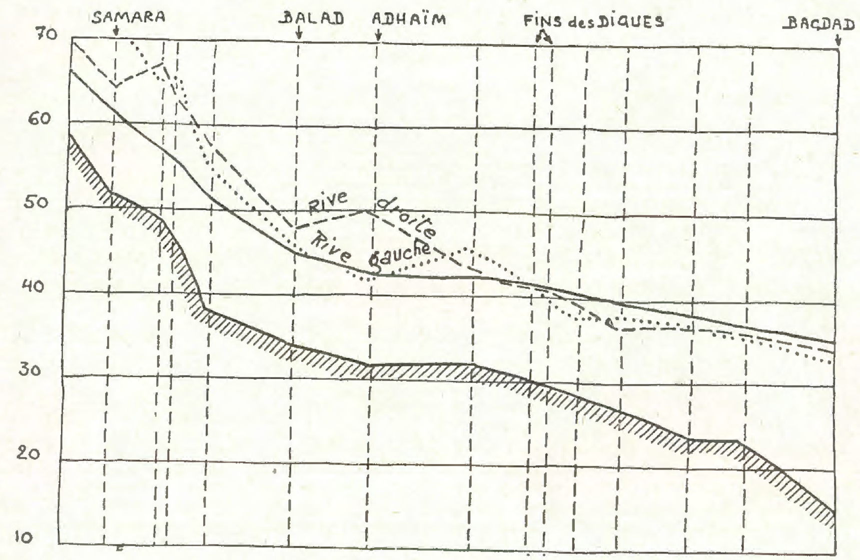


Fig. 9. — Profil longitudinal du Tigre en amont de Bagdad (niveau de l'eau et fond du lit) ainsi que de ses deux rives.

Dès Balad (fig. 9), le Tigre coule plus haut que les berges qu'il a édifiées. Il entre dans l'immense plaine alluviale qu'il a tendance à submerger d'autant plus qu'il l'aborde avec une vitesse assez grande et

que le flot de la Diyala, peu après Bagdad, lui coupe la route et l'oblige à ralentir son allure. Bagdad est ainsi presqu'annuellement menacée et investie de tous les côtés sans qu'il soit toujours possible d'éviter les catastrophes.

La Mésopotamie présente toutefois deux parties bien différentes qui sont fonction de la pente du fleuve. *De Balad à Kut,* la pente moyenne est encore supérieure à 6 cm./km. [1]; le pays est à peu près normalement drainé au moins en dehors de la période des hautes eaux. *De Kut à la mer* au contraire, la pente est si faible que cette partie de l'Irak est une contrée de marécages permanents dont on peut se demander s'ils seront jamais complètement drainés.

De même qu'il y a un Irak des plateaux et un Irak de la plaine, il y a une Mésopotamie de la plaine et une Mésopotamie des marais.

3. Profils transversaux (fig. 10 et tableau VI).

De Faish Khabour à Kut, le Tigre est un fleuve majestueux. Sa largeur varie de 160 à 242 m. à Mossoul, de 188 à 212 m. à Bagdad, de 278 à 312 m. à Kut. Les profondeurs aux basses et aux hautes eaux sont respectivement de : 2,43/5,63 ; 7,41/13,74 ; 5,32/8,75.

Le Tigre fait incontestablement figure de grand fleuve capable de charrier de grosses masses d'eau à des vitesses élevées. Près de 10 km. à l'heure à Mossoul en temps de crue. Ces vitesses se ralentissent en Mésopotamie au fur et à mesure que le lit a tendance à s'élargir et que la pente devient plus faible. A Kut, elles ne dépassent plus 3,5 km. à l'heure.

[1] « Pour les cours d'eau de plaine, les pentes oscillent normalement autour de 5 à 20 cm ». M. Pardé, *Fleuves et rivières*, p. 14 ; Paris, Colin 1947.

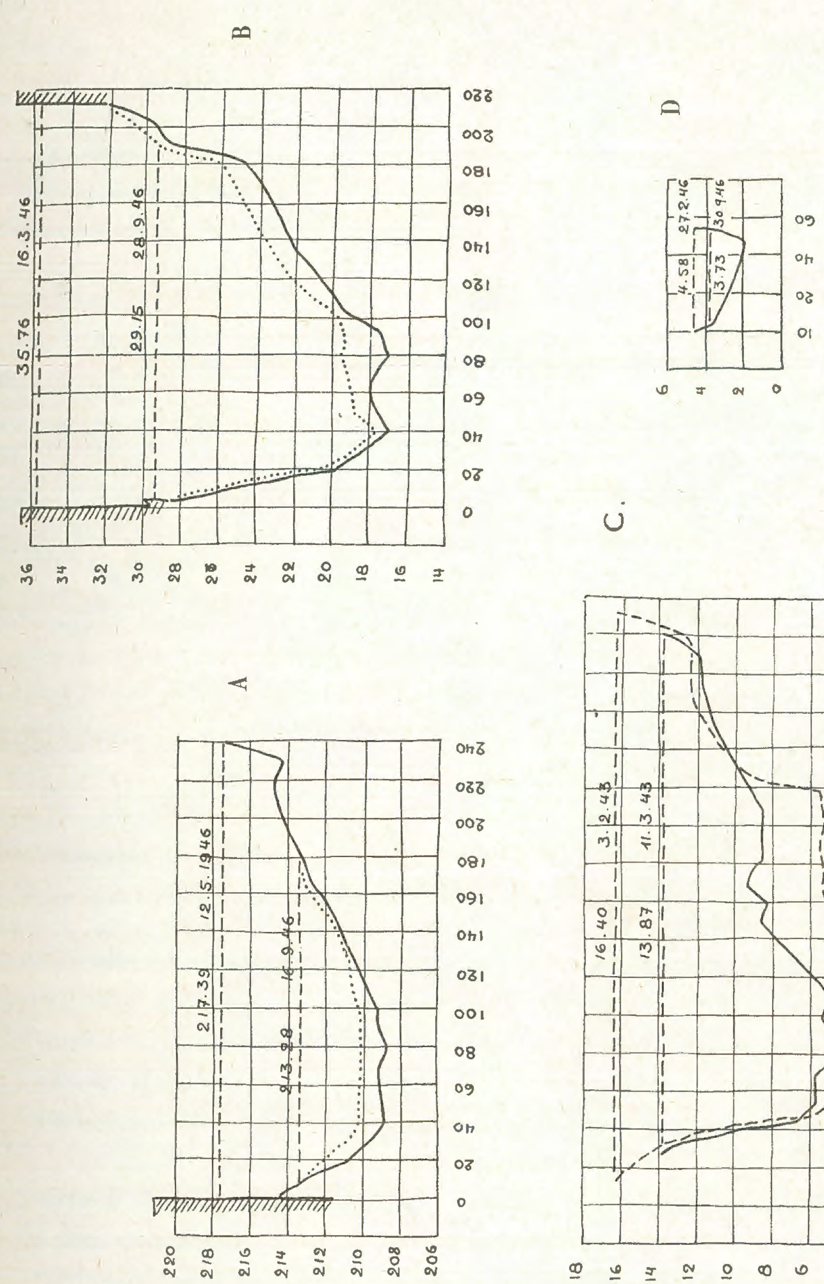


Fig. 10.
Profils transversaux du Tigre à Mossoul (A) Bagdad (B), Kut (C) et Qalat Saleh (D).

TABLEAU N° VI : PROFILS TRANSVERSAUX DU TIGRE ET DE SES AFFLUENTS.

	Date	Niveau (en m.)	Largeur du fleuve	Surface de la section du fleuve (en m²)	Profondeur moyenne	Vitesse moyenne (m./sec.)	Débit (m³/sec.)
Tigre, à Mossoul	12.5-46	217,39	242	1.362	5,63	2,75	3.740
Idem	16.9-46	213,28	160	388	2,43	0,57	220
Tigre, à Bagdad	16.3-46	35,76	212	2.914	13,74	2,44	7.116
Idem	28.9-46	29,15	188,5	1.397	7,41	0,24	337
Tigre, à Kut	11.3-43	16,40	312	2.613	8,65	1,01	2.648
Idem	3.2-43	13,87	278	1.478	5,32	0,52	771
Tigre, à Qalat Saleh	27.2-46	4,58	56	129	2,32	0,64	83
Idem	30.9-46	3,73	51	59	1,16	0,43	25,30
Grand Zab, à Eski Kelek.	15.4-46	248	258	874	2,44	2,52	231
Idem	15.9-46	246	86	335	3,90	0,44	148
Petit Zab, à Altunkupri.	21.2-46	252	157	337	2,14	2,12	715
Idem	13.7-46	250	120	110	0,92	1,72	191
Adhaim à Injanah	20.1-46	2,36	112	249	2,23	1,89	473
Idem	1.5-46	0,80	102	48	0,48	0,68	33
Diyala, à D. S.	—	67,28	241	342	1,42	1,04	359
Idem	—	66,59	218	213	0,97	0,20	43

Dans la dernière partie de son cours, le Tigre devient un fleuve exsangue. A Qalat Saleh, son lit n'a plus qu'une cinquantaine de mètres de large (51 à 56 m.) et de 1,16 à 2,32 m. de profondeur; autant dire qu'un homme peut le passer à pied aux basses eaux.

La différence considérable de débit qui existe entre la période de crue et celle d'étiage amène à cette dernière époque une réduction non moins grande de sa capacité de transport. Il s'envase alors sur une profondeur notable jusqu'à ce que les eaux de la prochaine crue le désensable à nouveau.

B. CLIMATOLOGIE.

Il suffira pour en avoir une idée de se reporter à ce qui en a été dit plus haut. Toutefois comme le bassin du Tigre déborde l'Irak vers le Nord, on donnera ici quelques chiffres complémentaires concernant la pluviosité de la région du Haut Tigre situé en Turquie.

TABLEAU N° VII : PLUVIOMÉTRIE DES BASSINS DU TIGRE ET DE L'EUPHRATE, SITUÉS EN TURQUIE.

Stations	Années d'observation	Altitude (m.)	Pluie (mm.)
Beytussebap	1950-51	1.500	930
Bitlis	1929-32, 40-41, 45-51	1.400	480
Cizré	1938-39, 41-51	400	675
Diyarbékir	1929-51	652	503
Hakkari	1950-51	1.650	492
Mardin	1939, 41-51	1.150	685
Siverek	1929-51	850	570
Siirt	1929-45, 47-51	875	750
Urfa	1929-32, 40-41, 45-51	1.400	480
Van	1932-51	590	366
Viransehir	1950-51	422	880

Au pied du Taurus arménien, Diyarbékir a 503 mm. et Mardin, 685 mm. Cizré au point où convergent les frontières turques, syrienne et irakienne, monte aussi à 675 mm.

Dans ces conditions, il est étonnant de ne pas trouver dans la montagne des chiffres de précipitation plus élevés. Bitlis ne reçoit que 480 mm.; Hakkari, 492; Siirt, 750. Il est vrai qu'il ne s'agit là que de stations relativement abritées. Comme pour le Zagros, la pluviosité de la montagne du Taurus est mal connue. Sur les hauteurs, elle est vraisemblablement plus élevée.

L'incertitude qui demeure cependant à son sujet ne permet pas de calculer encore directement l'indice de pluviosité du bassin du Tigre.

Il a été estimé aux chiffres suivants selon les différents secteurs [1] :

Tigre à l'amont de Mossoul : 690 mm.
Grand Zab à Girdmamouk : 740 mm.
Petit Zab à Altun Kupri : 660 mm.
Diyala à D. S. (Dj. Hamrin) : 340 mm.

2° Le régime du Tigre.

L'analyse peut s'en faire du triple point de vue des variations dans le temps (variations des débits mensuels ou des débits annuels), — de l'abondance moyenne, — et des variations du fleuve quand on le suit de l'amont à l'aval.

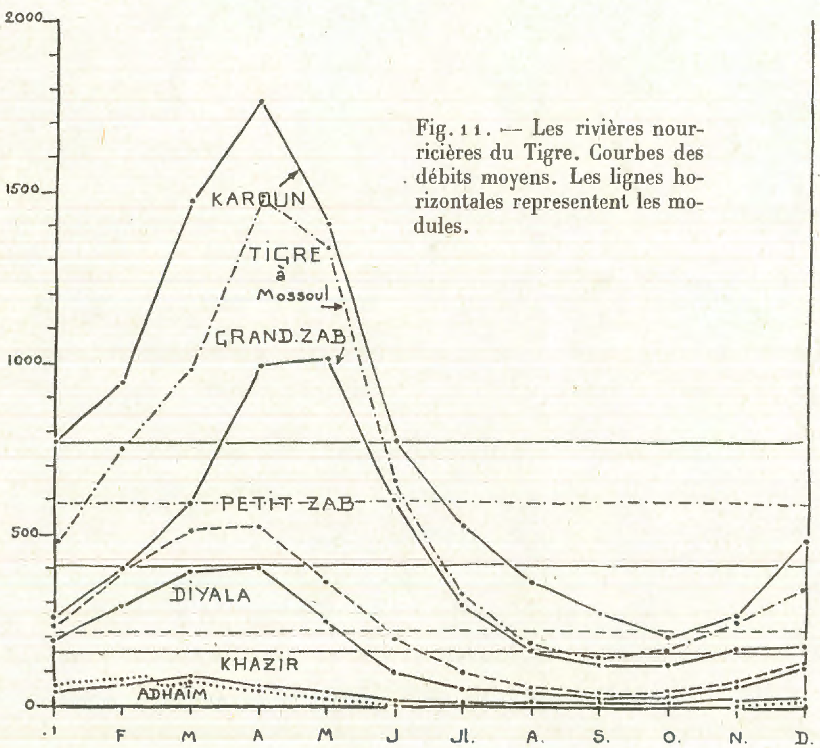


Fig. 11. — Les rivières nourricières du Tigre. Courbes des débits moyens. Les lignes horizontales representent les modules.

[1] Kholy, *ouvr. cité.*, p. 164. Ces chiffres diffèrent légèrement de ceux donnés par Ionides (cf. plus bas, tableau n° XI).

A. *Variations dans le temps.*

Les séries d'observations sont maintenant assez longues pour que l'on puisse caractériser non seulement l'évolution des débits au cours de l'année mais encore celle qui existe entre les débits annuels au cours des deux, trois ou même des quatre dernières décades.

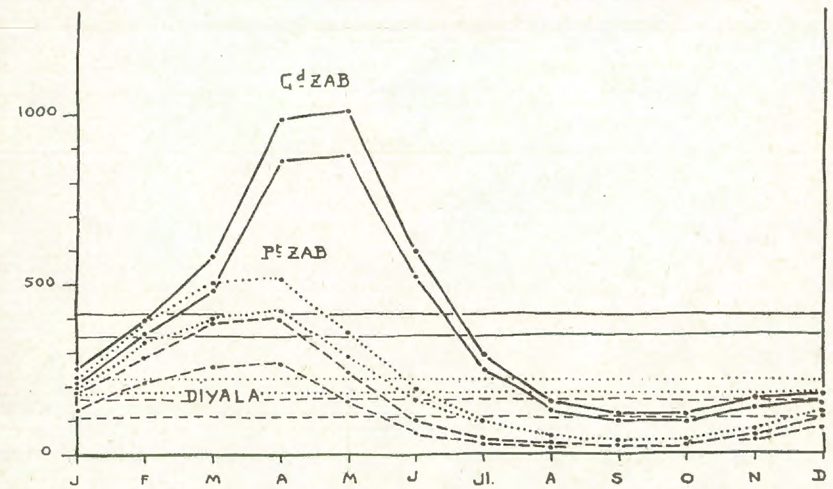


Fig. 12. — Courbes des débits moyens du Grand Zab à Bekhme et à Eski-Kelek, du Petit Zab à Dokhan et à Altun Kupri, de la Diyala au futur Barrage et à D. S. Les lignes horizontales représentent les modules.

1. Variations saisonnières (tableau n° VIII).

La similitude des courbes est frappante. *Les rivières nourricières du Tigre* (fig. 11 et 12) *comme le Tigre lui-même* (fig. 13) *montrent tous un étiage de saison chaude, une montée d'automne et d'hiver, des hautes eaux de printemps* [1].

[1] Nous reprenons ici les divisions de M. Pardé, *ouvr. cité*, p. 524 et suiv., qu'il n'y a pas lieu de changer.

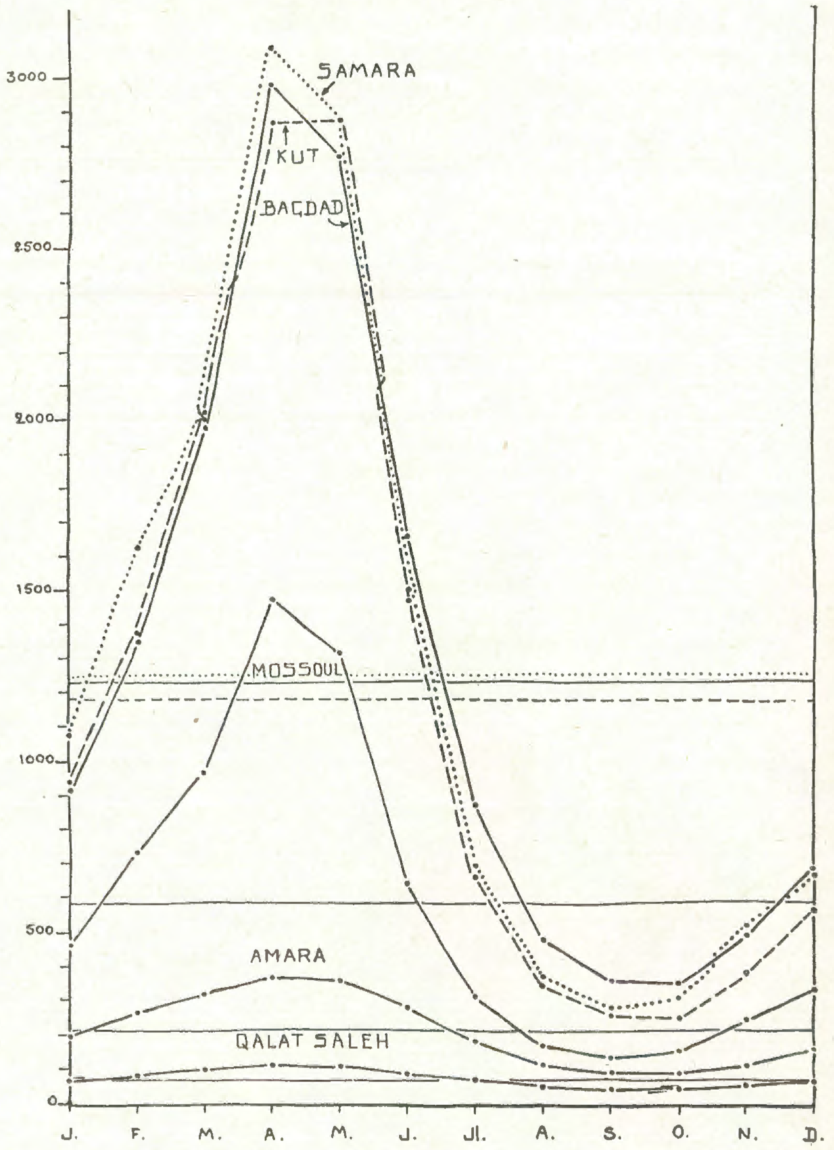


Fig. 13. — L'artère de drainage.
Courbe des débits moyens. Les lignes horizontales représentent les modules.

Tableau N° VIII : débits moyens du Tigre et de ses Affluents.

	Sources [1]	J.	F.	M.	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	Moyenne annuelle	Sources [1]	Crue Maximum		Etiage Minimum	
																Date	m³/sec. [2]	Date	m³/sec.
(1) Tigre, à Faish-Khabour (1931-1950)	Kh. App. (3)	—	—	—	Max.	—	—	—	—	Min.	—	—	—	—	Kh. (App. 4)	16-2-35	(12.70)	14-11 au 19-12-46	(4.80)
(2) Tigre, à Mossoul (1919-1951)	D. B.	474	739	969	*1.480*	1.320	653	320	175	**142**	162	251	342	585	D. B. et Kh.	17-2-35	6.100	21-9 au 1-11-47 12-9 à 18-10-47	88
(3) Khazir à Mangubah (1943-1952)	D. B.	38	60	*86*	59	38	14	10	8	**8**	9	14	21	30	D. B.	10-2-41	3.000	—	?
(3 A) Grand Zab, à Bekhme (1925-1946)	Haigh	222	356	486	*865*	*870*	526	251	131	**99**	**97**	140	150	349	Haigh	10-2-41	6.140	—	?
(4) Grand Zab, à Eski Kelek (1925-1952)	D. B.	258	400	586	991	*1.010*	601	294	162	**123**	**121**	166	177	407	Kh. App. (58)	10-2-41	7.175	—	?
(2) + (3) + (4)		770	1.199	1.641	*2.530*	2.368	1.268	624	345	**273**	292	431	540	1.022	—	—	10.175	—	?
(5) Tigre, à Shargat (1925-1950)	Kh. App. (14)	—	—	—	Max.	—	—	—	—	Min.	—	—	—	—	Kh. App. (15)	11-2-41	(152,54)	26-8 au 30-8-25 S. et O. 25	(146)
(5 A) Petit Zab, à Dokhan (1925-1948)	Haigh	198	335	398	*425*	288	161	88	50	**38**	**40**	67	107	183	Haigh	11-2-41	2.980	Sept. 30	21
(6) Petit Zab, à Altun Kupri (1925-1952)	D. B.	237	404	511	*519*	358	193	99	55	**42**	**45**	74	123	219	Kh. App. (66)	11-2-41	3.591	Sept. 44, 47 et 48	25
(2) + (3) + (4) + (6)		1.007	1.603	2.152	3.049	2.726	1.461	723	400	315	337	505	663	1.241	—	—	—	—	—
(7) Tigre, à Baiji (1922-1950)	Kh. App. (20)	—	—	—	Max.	—	—	—	—	Min.	—	—	—	—	Kh. App. (20)	11-2-41	(108,40)	2 au 10-11-26	(101,78)
(8) Tigre, à Samarrah (1933-1946)	Kh. App. (18)	1.083	1.631	2.019	*3.089*	2.875	1.474	700	376	**285**	314	526	672	1.254	Kh. App. (18)	12-2-41	12.500(?)	10 au 16-9-33	210
(9) Adhaïm, à Injanah (1933-1952)	D. B.	61	*76*	*74*	52	22	7	2	**1**	**1**	**1**	14	24	28	Kh. App. (73)	14-3-46	1.448	Eté	0
(2) + (3) + (4) + (6) + (9)		1.068	1.679	2.226	3.101	2.748	1.468	725	401	316	338	519	687	1.269	—	—	—	—	—
(10) Tigre, à Bagdad (1906-1951)	D. B.	922	1.355	1.985	*2.909*	2.777	1.661	870	480	360	**352**	496	682	1.236	Kh. App. (26)	13-2-41	13.000	20 au 24-9-30	158
(10 A) Diyala, à Sirwan (1924-1948)	Haigh	136	213	263	272	162	65	34	24	**22**	27	47	76	112	Haigh	14-3-46	2.394	—	?
(11) Diyala (1924-1952)	D. B.	190	294	393	*406*	245	97	53	37	**33**	40	68	112	164	Kh. App. (80)	14-3-46	3.420	23 au 27-8-32	15
(2) + (3) + (4) + (6) + (9) + (11)		1.258	1.973	2.619	*3.507*	2.993	1.565	778	438	349	378	587	799	1.433	—	—	—	—	—
(10) + (11)		1.112	1.649	2.378	*3.315*	3.022	1.758	923	517	393	392	564	794	1.400	—	—	—	—	—
(12) Tigre, à Salman Pak (1937-1950)	Kh. App. (30)	—	—	—	Max.	Max.	—	—	—	Min.	—	—	—	—	Kh. App. (31)	17-5-50	(32,97)	16-9 au 16-10-47	(24,22)
(13) Tigre, au barrage de Kut (1930-1946)	Kh. App. (42)	935	1.476	2.019	*2.869*	*2.870*	1.505	658	352	**261**	**253**	381	566	1.179	Kh. App. (36)	18-5-50	(19,40) 3.000	11-11-47	(9,46) 10
(14) Tigre, à Amarah (1918-1948)	Kh. App. (43)	207	274	331	*374*	364	286	189	121	**95**	**91**	115	162	218	Kh. App. (43)	28-2-38	558	25-11-48	24
(15) Tigre, à Qalat Saleh (1922-1948)	Kh. App. (51)	74	91	106	*119*	117	97	73	56	**48**	**47**	54	64	78	Kh. App. (51)	6-4-22	179	30 et 31-12-48	11
(16) Karoun, à Ahwaz (1894-1930)	Ionides	770	945	1.470	*1.760*	1.400	770	525	360	270	**200**	260	480	767	—	—	—	—	—

[1] Renvois aux ouvrages cités : Kholy (Kh.); Haigh; Ionidès; Development Board (D. B.).

[2] En mètres quand les chiffres sont entre parenthèses.

a. Etiage de saison chaude. — *Il a lieu partout à la fin de l'été, ordinairement en septembre.* Rien ne montre mieux l'influence du climat dont les deux saisons sèche et humide se répercutent dans le domaine hydrologique. Les pluies et les eaux de fonte des neiges une fois écoulées, le Tigre ne cesse de s'appauvrir. L'alimentation lui fait défaut et ce qui lui reste d'eau à drainer est évaporée en grande partie par l'intense chaleur de l'été.

Le mois le plus bas n'est pas cependant toujours le même. Pour le Khazir et l'Adhaïm, l'étiage est atteint dès août, pratiquement même dès juillet, et il s'étend sur trois mois. Ne drainant que le piedmont du Zagros et les premières pentes de la montagne mais ne venant pas de l'intérieur de celle-ci, l'été les tarit à peu près complètement. *Le Grand Zab au contraire et surtout le Karoun ne connaissent l'étiage qu'en octobre.* Cela donne à supposer que leurs réserves souterraines sont plus abondantes que celles des autres rivières pour qu'elles puissent parvenir ainsi jusqu'à la nouvelle saison des pluies sans être totalement épuisées. Toutes les rivières nourricières du Tigre, à l'exception des deux premières (Khazir, Adhaïm), doivent bénéficier d'ailleurs de la même remarque. Sans les ressources stockées sous terre, dans les zones karstiques notamment, elles connaîtraient un étiage beaucoup plus prématuré et s'assècheraient même peut-être complètement.

Le Tigre connaît aussi son étiage en septembre, au moins dans la partie supérieure de son cours. A partir de Bagdad, les basses eaux ont lieu au mois d'octobre.

b. Montée d'automne et d'hiver. — C'est durant le mois de novembre que les courbes commencent à marquer un relèvement des débits en rapport avec les premières pluies. Ce redressement se poursuit en s'accentuant légèrement en décembre et janvier mais il ne se fait pas partout de la même façon. *Le Khazir, le Petit Zab, l'Adhaïm, la Diyala et le Karoun dépassent leur module dès le mois de janvier, tandis que le Grand Zab et le Tigre, de Mossoul au Chatt el Arab, ne le rattrapent qu'en février.* Cette dernière constatation laisse déjà prévoir des rétentions nivéales importantes.

c. Hautes eaux de printemps. — Dès février, les courbes exacerbent leur montée, au moins sur les rivières principales, et commencent à

dessiner de vigoureux clochers. *Leur culmination se produit en février pour l'Adhaïm, en mars pour le Khazir,* rivières courtes dont la courbe suit au plus près celle de la pluviosité. *Pour le Petit Zab, la Diyala, le Karoun et le Tigre, elle n'a lieu qu'en avril* ce qui, étant donnée la rapidité d'écoulement des eaux, traduit une rétention nivéale importante car avril est déjà un mois où les précipitations faiblissent très nettement. L'influence de la fonte des neiges se révèle aussi d'ailleurs à cet autre fait que le Tigre à Mossoul et le Karoun ont encore en mai des débits assez proches de ceux d'avril, sur le Grand Zab même le maximum est atteint durant ce dernier mois.

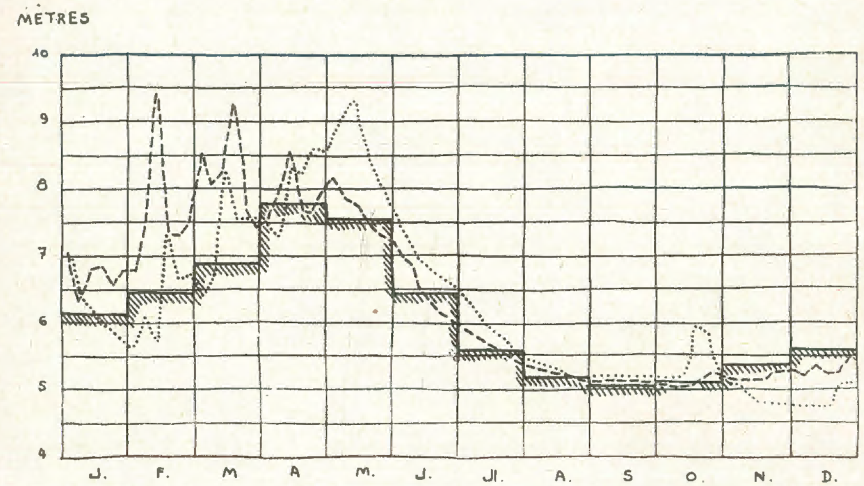
Après la cessation des pluies et la fin de la fonte des neiges, les courbes s'effondrent avec une brusquerie encore plus grande qu'elles n'avaient mise à monter. *Selon la prédominance de leur genre d'alimentation la décrue s'amorce en avril, en mai ou en juin.* Le passage au-dessous du module qui a lieu dès mai pour l'Adhaïm, se produit ordinairement en juin (Khazir, Petit Zab, Diyala) ou en juillet (Tigre de Mossoul au Chatt el Arab, Grand Zab).

D'une manière générale par conséquent, les rivières nourricières du Tigre comme le Tigre lui-même suivent de très près les courbes de précipitations. La seule diversité, minime à la vérité, qui s'y introduit, est en relation avec la manière dont ont lieu ces précipitations. Les bassins du Haut Tigre, du Grand Zab et du Karoun, plus élevés et plus enneigés que les autres donnent lieu à des hautes eaux plus tardives que ceux du Petit Zab et de la Diyala où la montagne a une altitude plus faible et où les neiges sont moins abondantes. Ces nuances mises à part, on peut constater qu'aucune autre cause importante ne paraît influer sur la courbe des débits mensuels. Le karst ainsi qu'on l'a dit plus haut intervient sans doute pour soutenir les débits d'été; il n'a pas cependant d'influence décisive.

Il ne stocke certainement pas une quantité d'eau susceptible de déplacer les maximum et minimum d'une manière suffisamment notable pour être apparente.

2. Variations annuelles (fig. 14 et 15 — tableau n° IX).

Le rôle des précipitations est donc le facteur déterminant qui explique l'allure des courbes saisonnières. Il s'en faut cependant de beaucoup que les années soient rigoureusement semblables les unes aux autres. *Les périodes de basses eaux et surtout de hautes eaux peuvent varier beaucoup d'une année à l'autre.*



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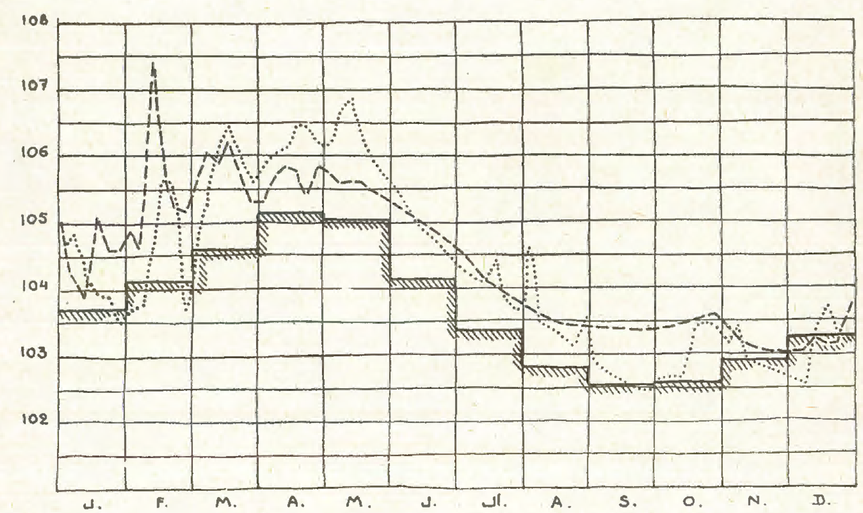


B

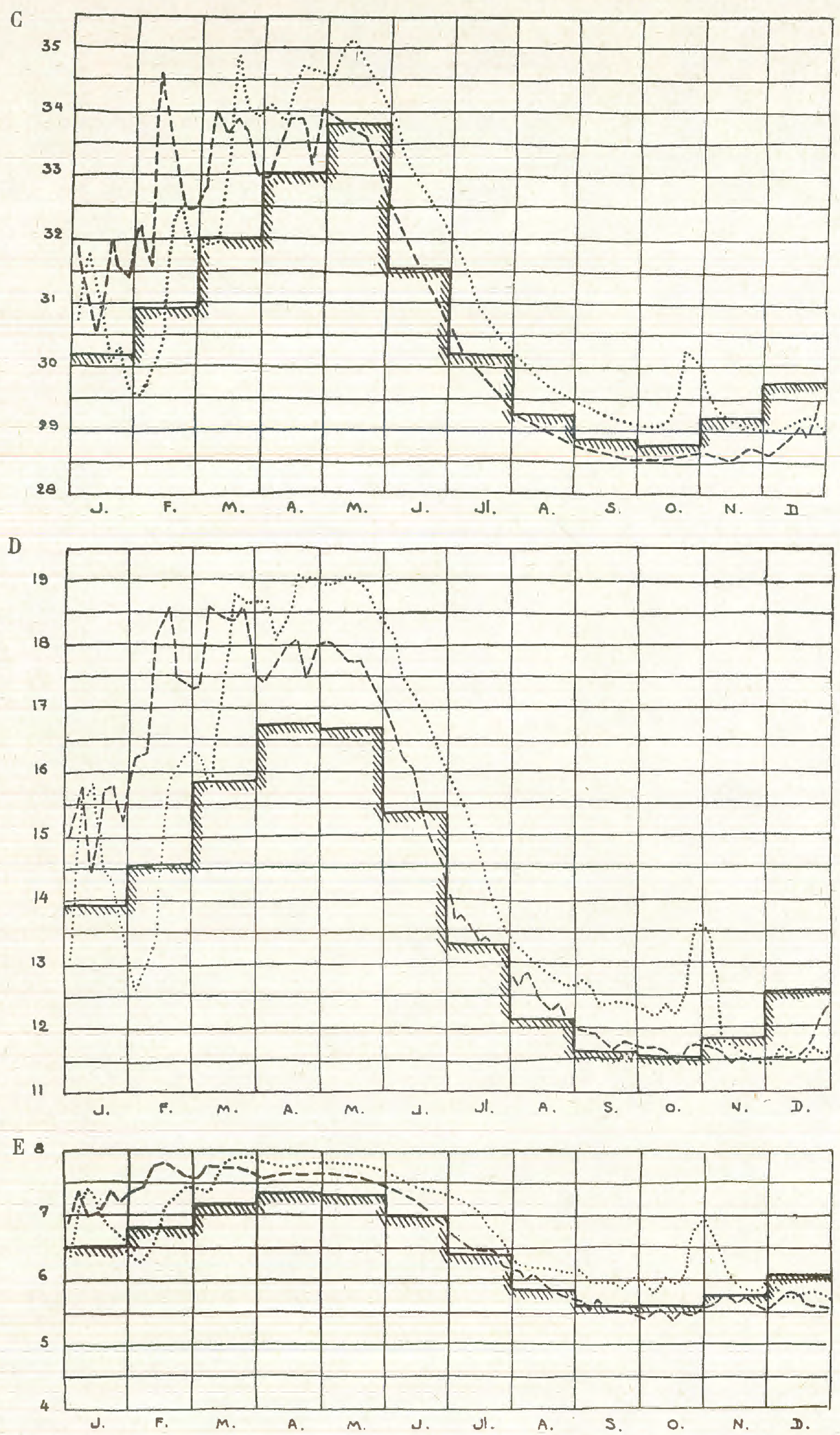
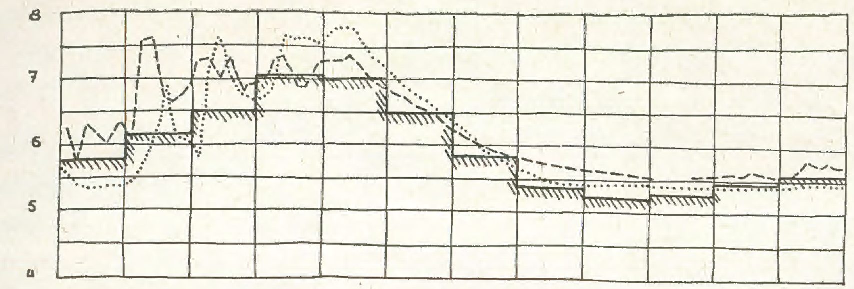
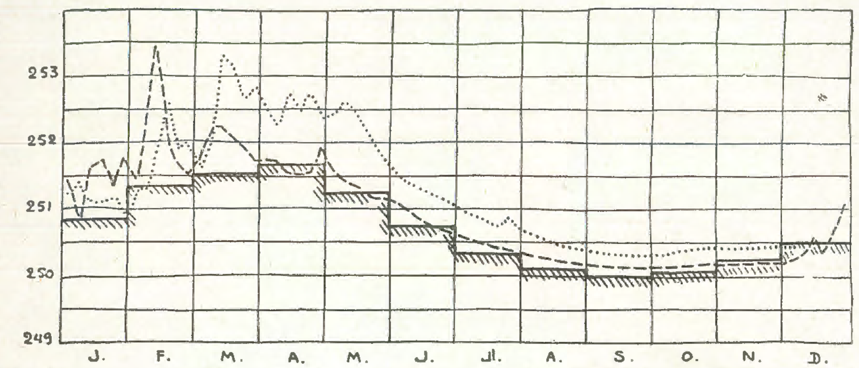


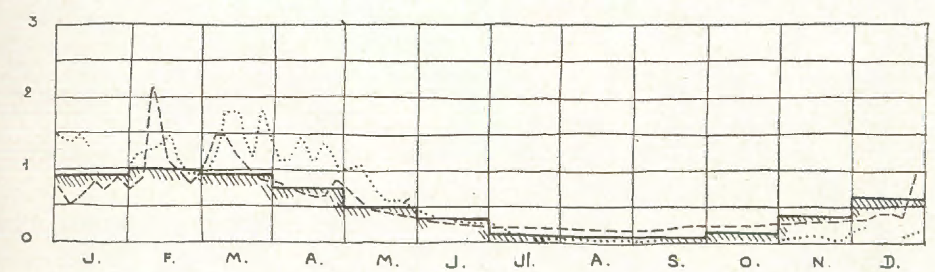
Fig. 14. — Courbes des débits du Tigre à Faish Khabour (A), Baiji (B), Bagdad (C), Kut (D) et Amara (E). Courbes moyennes et courbes de 1936 (pointillés) et 1941 (tiretés).



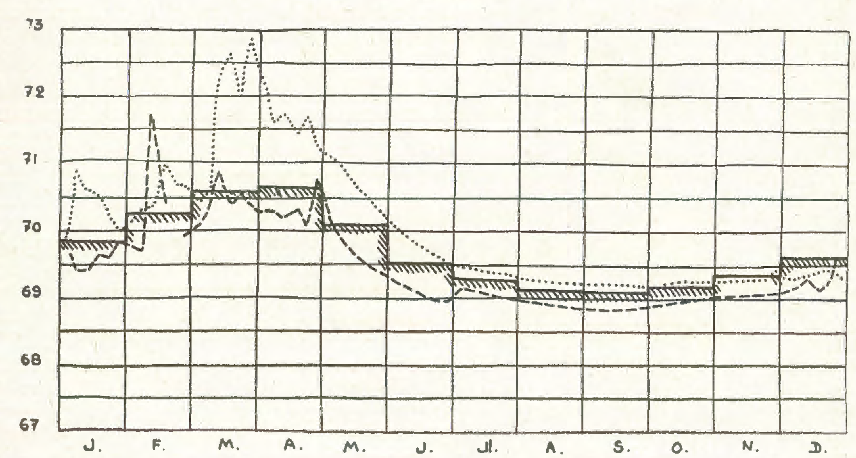
A. Grand Zab.



B. Petit Zab.



C. Adhaïm.



D. Diyala.

Fig. 15. — Courbes des débits du Grand Zab, du Petit Zab, de l'Adhaïm et de la Diyala. Courbes moyennes et courbes de 1936 (pointillés) et de 1941 (tiretés).

Tableau N° IX : Fréquence des Crues et des Étiages selon les mois *(d'après les chiffres publiés par Kholy)*.

	Nombre d'années d'observations	Date la plus avancée du débit max. extrême	Date la plus tardive du débit max. extrême	Debits maximum extrême atteint (en nombre de fois)								Date la plus avancée du débit min. extrême	Date la plus tardive du débit min. extrême	Debit minimum extrême atteint (en nombre de fois)						
				O.	N.	D.	J.	F.	M.	A.	M.			Jl.	A.	S.	O.	N.	D.	J.
Tigre, à Faish-Khabour (1931-1950)	20	2.1 (1931)	15.5 (1936)	—	—	—	4	2	2	8	4	27.7 (1931)	19,12 (1946)	1	1	6	7	4	1	—
Tigre, à Mossoul (1919-1950)	32	28.11 (1924)	17.5 (1950)	—	1	1	3	5	4	11	7	1.8 (1930)	15.12 (1946)	—	2	14	13	2	1	—
Tigre, à Shargat (1925-1950)	26	18.12 (1930)	16.5 (1932)	—	—	1	1	2	5	9	8	18.8 (1942)	19.12 (1949)	—	3	6	14	1	2	—
Tigre, à Baiji (1922-1950)	29	23.12 (1933)	24.5 (1942)	—	—	1	1	4	3	15	5	20.7 (1935)	16.12 (1936)	1	—	7	14	3	3	—
Tigre, à Bagdad (1906-1950)	45	3.12 (1914)	19.5 (1932)	—	—	1	1	4	6	22	9	19.9 (1913)	9.1 (1933)	—	—	3	26	9	4	1
Tigre, à Salman Pak (1937-1950)	14	23.1 (1945)	17.5 (1950)	—	—	—	1	1	2	4	6	16.9 (1947)	20.1 (1949)	—	—	1	9	2	1	1
Tigre, au barrage de Kut (1918-1950)	33	25.1 (1945)	21.5 (1932)	—	—	—	1	2	6	14	10	2.8 (1939)	17.1 (1949)	—	1	1	16	8	6	1
Tigre à Amarah (1918-1950)	33	16.1 (1926)	6.5 (1948)	—	—	—	2	9	9	10	3	14.9 (1930)	19.12 (1940)	—	—	6	8	15	4	—
Tigre à Qalat Saleh (1922-1950)	29	26.1 (1945)	20.5 (1950)	—	—	—	1	4	6	14	4	13.9 (1930)	31.12 (1948)	—	—	5	9	11	4	—
Grand Zab, à Guwair (1930-1947)	18	27.11 (1936)	1.5 (1938)	—	1	1	1	3	4	4	1	21.9 (1939)	28.1 (1946)	—	—	2	6	5	1	2
Petit Zab, à Altun Kupri (1931-1948)	18	22.12 (1933)	1.5 (1948)	—	—	1	4	6	4	2	1	12.9 (1945)	12.10 (1939)	—	—	9	9	—	—	—
Adhaïm, à Injanah (1934-1947)	14	8.12 (1938)	1.4 (1935)	—	—	1	2	5	5	1	—	—	—	—	—	—	—	—	—	—
Diyala, à D. S. (1924-1950)	27	20.11 (1944)	13.4 (1937)	—	1	2	1	11	9	2	—	23.8 (1932)	27.11 (1938)	—	5	20	1	1	—	—

Sur le tableau n° IX, l'on a figuré les dates extrêmes où les débits instantanés (max. ou min.) ont été enregistrés. L'on y a noté aussi la fréquence où le phénomène s'était produit durant chaque mois.

Ce tableau est très éclairant. L'on peut constater en effet que les rivières nourricières du Tigre peuvent rouler leur maximum d'eau dès le mois de décembre et même dès la fin de novembre et que le Tigre lui-même peut être gonflé au maximum dès le mois de janvier. A l'extrême opposé, la plus grande crue ne se produit quelquefois qu'en mai sauf pour l'Adhaïm et la Diyala où elle n'est jamais plus tardive que le début d'avril. *C'est donc durant une période de cinq mois que les crues peuvent être menaçantes.*

Les variations des plus grands étiages trahissent des phénomènes semblables. Les plus précoces ont lieu en août, parfois même en juillet mais ils peuvent s'attarder jusqu'en janvier.

Le Tigre est donc un fleuve beaucoup plus vivant et irrégulier qu'on ne pourrait le supposer au premier abord puisque crues et étiages peuvent s'y rencontrer durant le même mois. Ainsi en 1946, il a connu ses plus basses eaux à Faish Khabour le 19 décembre tandis qu'en

1931, il a eu ses plus hautes eaux le 2 janvier. Il était au plus bas à Baiji le 19 décembre 1949 et au plus haut à la traversée de la même localité le 18 décembre 1930. Les exemples pourraient être multipliés pour le Tigre comme pour ses affluents. Le Grand Zab a connu ainsi ses plus basses eaux en 1946 le 28 janvier tandis qu'en 1936 il avait atteint son maximum dès le 27 novembre.

Ces variations des crues et des étiages soulignent bien le rôle prépondérant des précipitations atmosphériques et de la nature de celles-ci. Selon que les pluies sont plus ou moins précoces et plus ou moins abondantes, selon aussi que les précipitations se font principalement sous forme de pluies ou de neiges, le régime du Tigre est susceptible de varier très notablement d'une année à l'autre (fig. 14 et 15). Il enregistre avec beaucoup de fidélité les moindres pulsations climatologiques. L'emmagasinement des eaux en profondeur ne paraît avoir qu'un rôle très faible, il ne régularise pas le régime des eaux comme au Liban et en Syrie.

La publication des débits moyens année par année sur une période de temps assez longue (tableau n° X) suggère des remarques non moins intéressantes. Les modules employés ici sont généralement plus forts que ceux qu'avait utilisé M. Pardé et qui avaient été calculés sur des laps de temps beaucoup plus courts s'arrêtant en 1932 alors que les séries sur lesquelles nous nous appuyons vont jusqu'en 1950 environ.

De l'analyse des chiffres qu'il possédait pour Bagdad à la date où il écrivait, M. Pardé concluait que « ou bien, en Mésopotamie, les groupes d'années de même tendance sont d'habitude ou peuvent être occasionnellement plus longs qu'en Europe, ou bien nous assistons à un appauvrissement grave et non encore terminé, qui risque, s'il se poursuit au même rythme, d'annihiler bel et bien le Tigre en un demi siècle ou un siècle. Bien que penchant pour la première hypothèse, M. Pardé reconnaissait qu'« une réduction générale des débits moyens depuis 25 ou 30 ans paraît vraisemblable» [1].

L'observation des débits moyens annuels jusqu'en 1952 donne à penser qu'il n'y a sans doute pas à craindre un assèchement de l'Irak.

[1] M. PARDÉ, *ouvr. cité*, p. 541-542.

TABLEAU N° X : VARIATIONS DES DÉBITS ANNUELS (TIGRE ET AFFLUENTS).

Années	Tigre (Mossoul)	Tigre (Bagdad)	Tigre (Kut)	Tigre (Amara)	Gd. Zab (Eski Kelek)	Pt. Zab (Altun Kupri)	Adhaïm (Injanah)	Diyala (D. S.)
1920	565	1.200	—	232	—	—	—	—
1921	359	1.020	—	220	—	—	—	—
1922	537	1.460	—	260	—	—	—	—
1923	625	1.520	—	264	—	—	—	—
1924	450	1.020	—	214	—	—	—	154
1925	312	630	—	171	142	157	—	110
1926	696	1.510	—	268	452	298	—	254
1927	411	986	—	206	319	198	—	143
1928	446	986	—	203	304	208	—	139
1929	633	1.320	—	237	484	248	—	106
1930	222	499	521	152	192	114	—	102
1931	548	986	927	217	319	178	—	101
1932	402	877	837	191	363	159	—	103
1933	399	949	935	212	355	234	—	180
1934	382	863	846	205	286	190	68	152
1935	556	993	1.070	223	310	162	5	93
1936	548	1.140	1.144	249	370	205	34	194
1937	472	1.130	1.122	254	427	237	32	143
1938	696	1.430	1.570	301	536	267	41	242
1939	703	1.380	1.510	258	558	281	36	255
1940	771	1.590	1.561	249	537	340	45	248
1941	794	1.550	1.504	244	499	259	23	178
1942	879	1.640	1.558	220	550	236	11	150
1943	741	1.390	1.284	190	382	197	22	196
1944	552	1.190	940	149	443	154	12	107
1945	518	1.030	818	146	367	198	28	167
1946	835	1.670	1.893	224	627	352	51	298
1947	491	911	—	137	367	176	6	104
1948	801	1.230	—	148	449	155	7	89
1949	618	1.330	—	—	535	273	40	257
1950	644	1.330	—	—	501	325	29	246
1951	486	725	—	—	301	125	7	116
Moyenne	585	1.236	1.179	218	407	219	28	164
	D. B.	D. B.	Kh.	Kh.	D. B.	D. B.	D. B.	D. B.

N. B. — Les séries sont prises en 1920 — Elles sont quelquefois plus longues.

Les courbes des différentes rivières (fig. 16 et tableau X) *soulignent en effet un premier fait, à savoir le caractère parfaitement synchrone des variations, qu'il s'agisse de l'Euphrate, du Tigre ou des affluents de celui-ci.* Ce sont durant les mêmes périodes d'années que se produisent les maxima ou les minima. Jusqu'en 1930, les débits moyens annuels sont tantôt

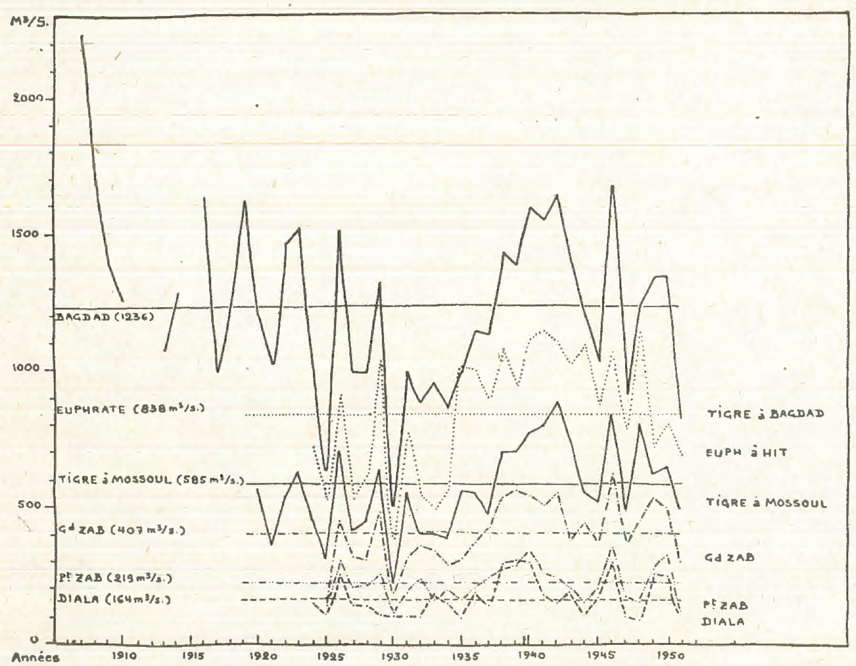


Fig. 16. — Courbes de variation des débits moyens annuels. Les traits horizontaux représentent le module calculé en 1951.

au-dessus, tantôt au-dessous (plus souvent au-dessous qu'au-dessus) du module arrêté en 1951 [1]. Puis vient une longue période de sous alimentation où toutes les rivières restent au-dessous de leur module normal, elle dure jusqu'en 1935 pour l'Euphrate, jusqu'en 1936 pour le Tigre à Bagdad et à Mossoul, jusqu'en 1937 pour le Grand Zab et le

[1] C'est la période sur laquelle s'est appuyé M. Pardé. A Bagdad, seul point où l'on ait des observations remontant au début du siècle, elle trahit une baisse notable par rapport à la période antérieure à 1914.

Petit Zab. Mais celle-ci est suivie à son tour par une période de suralimentation ininterrompue qui s'étend jusqu'à 1944 pour le Tigre à Mossoul et à Bagdad, jusqu'en 1943 pour le Grand Zab et le Petit Zab, jusqu'en 1947 pour l'Euphrate. A l'heure actuelle, les débits moyens oscillent à nouveau autour du module tout en paraissant bien s'orienter à nouveau vers un effondrement.

A quoi tiennent ces variations? Leur parfait synchronisme laisse présager qu'elles sont toutes en dépendance d'une cause unique qui ne peut être que d'ordre climatologique. Le Tigre et ses affluents si sensibles, ainsi qu'on l'a vu, aux précipitations et à la manière dont elles se produisaient au cours de l'année, doivent l'être aussi à leur plus ou moins grande abondance selon les années. Le fait est infiniment probable. Il manque pour le prouver d'avoir des séries climatologiques suffisamment longues et de pouvoir construire la courbe des variations des précipitations. Ce qu'on a dit plus haut cependant, de la variabilité des pluies beaucoup plus grande en Irak qu'en Syrie et en Palestine montre déjà qu'il n'y a pas à s'étonner de retrouver dans le régime du Tigre une variabilité également très accentuée.

B. *Abondance moyenne.*

L'abondance moyenne se caractérise par le module relatif ainsi que par l'indice, le déficit et le coefficient d'écoulement. Les deux premiers peuvent être calculés aisément, il n'en est pas de même des deux derniers quand on ne connaît pas de façon précise l'indice de pluviosité.

1. Modules relatifs (tableau n° XI). — *Dans le classement des rivières nourricières du Tigre ou des différents secteurs de celui-ci, le Grand Zab vient très nettement en tête avec 19,8 l./sec./km²* ce qui représente une fort belle moyenne. Il n'y a pas lieu de s'en étonner car le grand Zab draine un bassin, montagneux pour la plus grande partie et fort bien arrosé [1].

[1] Il faut prendre garde cependant que ce module relatif comme ceux dont il va être question pèche par excès du fait que la superficie du bassin considérée est celle du bassin à la station de jaugeage. Celle-ci est plus petite que la superficie au confluent et la différence ainsi soustraite intéresse une région peu ou pas pluvieuse où les modules relatifs par conséquent ne peuvent avoir tendance qu'à faiblir. La remarque vaut déjà pour le grand Zab mais encore plus pour les autres affluents.

TABLEAU N° XI.

	(1) Période	(2) Bassin en km²	(3) Débit moyen brut (m³/sec)	(3) Débit moyen relatif l./S/km²	(4) P : Pluie tombée (en mm)	(5) P' : Pluie écoulée (en mm)	(6) Déficit d'écoulement = P – P'	(7) Coefficient d'écoulement = P' : P
Tigre à Mossoul.	1919-1952	54.898	585	10,65	720	334	386	0,46
Tigre à Bagdad.	1906-1951	134.259	1.236	9,20	790	290	500	0,36
Khazir à Mangubah.	1943-1952	2.935	30	10,22	—	321	—	—
Grand Zab à Eski Kelek. .	1925-1952	20.463	407	19,8	780	624	156	0,80
Petit Zab à Altun Kupri. .	1925-1952	15.622	219	14	700	441	259	0,63
Adhaïm à Injanah.	1933-1952	9.840	28	2,8	—	88	—	—
Diyala.	1924-1952	29.678	164	5,5	430	173	257	0,40
Karoun à Ahwaz.	1894-1930	51.000	766	15	770	470	300	0,61

(4) D'après Ionides. Sujet à caution.
(6) et (7) Sujets à cautions puisque (4) l'est.

Assez loin derrière lui, se groupent le Karoun avec 15 l./sec./km², le Petit Zab avec 14 l., le Tigre à Mossoul avec 10,65 l., le Khazir avec 10,22 l., le Tigre à Bagdad avec 9,20 l. [1]. Ces chiffres encore honorables pour le Karoun et le Petit Zab à cause de leur vaste bassin montagneux montrent un fléchissement marqué pour le Khazir qui ne draine plus que le piedmont du Zagros et pour le Tigre tant à Mossoul qu'à Bagdad qui doit traverser une région étendue où non seulement il ne s'alimente plus mais où encore il s'appauvrit. Le fait est particulièrement sensible entre Mossoul et Bagdad ; sur ce trajet, le Tigre bien qu'il y reçoive les deux Zab et l'Adhaïm voit son module relatif tomber de 10,65 l./sec./km² à 9,20 l./sec./km².

Avec la Diyala et ses 5,5 l. /sec./km², l'Adhaïm et ses 2,8 l., c'est à une véritable annihilation que l'on assiste. Les modules relatifs reflètent la configuration de leurs bassins où l'élément montagneux ne prédomine plus ; ils trahissent aussi une abondance de pluies plus faible due à une latitude plus basse et à des montagnes moins élevées.

2. Indices, déficits et coefficients d'écoulement. — *L'indice d'écoulement* peut être calculé d'une manière sûre à partir des débits moyens et de la superficie des bassins, ou bien à partir des débits-moyens relatifs.

Il *est de 88 mm. à Injanah pour l'Adhaïm, de 173 mm. pour la Diyala, de 290 mm. pour le Tigre à Bagdad, de 334 mm. pour le Tigre à Mossoul, de 321 mm. pour le Khazir à Mangubah,* rivières qui englobent toutes des espaces désertiques plus ou moins vastes. Il est beaucoup plus fort là où les montagnes sont plus étendues ; *on trouve alors en effet : 441 mm. pour le Petit Zab à Altun Kupri, 470 mm. pour le Karoun à Ahwaz et surtout 624 mm. pour le grand Zab à Eski Kekek.*

L'indice de pluviosité au contraire est très mal connu et les chiffres donnés ne sont que des estimations sujettes à caution [2]. Dans la mesure

[1] Ces chiffres diffèrent de ceux fournis par M. PARDÉ, *ouvr. cité,* du fait surtout d'un planimétrage inexact des bassins que donne l'ouvrage de M. G. Ionides. Beaucoup de territoires désertiques en sont éliminés (M. Pardé en avait la remarque lui-même, voir, *ouvr. cité :* Tableau N° II, note 13, p. 537).

[2] Nous avons essayé de le calculer d'après le tableau donné par M. Pardé (*Les abaques de M. W. Wundt pour évaluer les débits moyens annuels des rivières d'après les précipitations et les températures — Annales de géographie,* LXIII, n° 335, p. 53,

où on peut y ajouter foi, on s'aperçoit que le *coefficient d'écoulement* du Grand Zab est très fort (0,80) de même que ceux du Petit Zab (0,63) et du Karoun (0,61). Les autres (Tigre à Mossoul : 0,46 et à Bagdad : 0,36; Diyala : 0,40) dénotent au contraire un déficit d'écoulement beaucoup plus accentué.

Quoi qu'il en soit exactement de ces chiffres, il est vraisemblable que la raideur des pentes, la vitesse de propagation des eaux, la concentration des précipitations en hiver, favorisent des coefficients plus élevées que ceux qu'on attendrait dans un pays aussi chaud que l'Irak.

C. *Variations du fleuve d'amont en aval.*

Il reste à examiner les variations du fleuve qui se produisent le long de son cours. Si l'on suit le Tigre de l'amont à l'aval, trois secteurs se laissent facilement distinguer :

— un secteur de croissance : de Diyarbékir à Samara (780 km.),

— un secteur d'écoulement où pertes et gains se compensent : de Samara à Kut (488 km.),

— un secteur de dépérissement : de Kut au Chatt el Arab (450 km.).

1. Secteur de croissance : de Diyarbékir à Samara.

Le Tigre n'est vraiment lui-même qu'après le confluent du Petit Zab. A Mossoul en effet, son débit moyen est encore inférieur à celui du Karoun. *C'est donc la conjonction du Haut Tigre et des deux Zab qui donnent naissance au fleuve.*

Jusqu'à Samara, il draine un bassin où la surface des montagnes, c'est-à-dire de la zone d'alimentation réelle, ne fait qu'augmenter, alors que la région plane reste à peu près semblable à elle-même. Les pentes sont fortes et ne s'abaissent pas au-dessous de 50 cm./km. (1/2.000^e) de telle sorte que l'évacuation des eaux est rapide. Le flot met 30 heures pour aller de Diyarbékir à Faish Khabour (300 km.), 24 heures de Faish Khabour à Mossoul (188 km.), 42 heures de Mossoul à Samara

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janv.-fév., 1954) mais les valeurs trouvées pour les différents bassins paraissent beaucoup trop fortes pour pouvoir être retenues.

(292 km.). Sur ses affluents, les vitesses de propagation des eaux doivent être encore plus rapides. Le Tigre n'a donc guère le temps de perdre ses eaux par infiltration ou par évaporation, d'autant plus que solidement encadré par sa vallée, il n'a pas la possibilité de s'étaler beaucoup en largeur et de provoquer ainsi des inondations qui favoriseraient celle-ci.

Partout le mois des plus hautes eaux est avril. Mai le suit de près, surtout après le confluent du Grand Zab dont l'alimentation est principalement nivale. Septembre est jusqu'à Samarra le mois des étiages. Des fluctuations importantes se produisent cependant quant à la date où les débits instantanés maximum sont susceptibles de se produire (Tableau n° IX). On l'a vu se produire dès décembre, et même dès novembre à Mossoul. D'une manière générale, elle a tendance à se rapprocher du mois où les débits mensuels sont les plus élevés, au fur et à mesure qu'on progresse vers l'aval. Il en est de même pour le débit minimum qui a lieu en août, ou même en juillet à l'amont du confluent du Petit Zab mais qui après celui-ci n'est jamais avant septembre; le mois le plus tardif pouvant être décembre.

Le débit dans cette section du fleuve ne fait qu'augmenter : de 585 m^3/sec. à Mossoul, il passe à 1254 m^3/sec. à Samara. L'apport des Zab le double donc entre ces deux villes.

Il est intéressant de noter que les pertes paraissent inexistantes. L'additionnement des débits du Tigre à Mossoul, du Khazir à Mangubah et des Zab à Eski Kelek et à Altun Kupri, donne un débit théorique de 1241 m^3/sec. Or à Samara le Tigre roule 1.254 m^3/sec. Le peu d'importance de l'irrigation dans ce secteur du fleuve explique sans doute ce maintien du débit.

2. Secteur d'écoulement où pertes et gains se compensent : de Samara à Kut.

La comparaison des trois courbes de Samara, de Bagdad et de Kut est éloquente. Non seulement elles se ressemblent dans tous leurs détails mais encore elles se superposent presque les unes aux autres. Sur 488 km., les débits du Tigre et leurs variations demeurent semblables à eux-mêmes.

Le bassin a pourtant augmenté dans de fortes proportions. De 111.681 km² à Samara, il passe à 166.155 km² au confluent de la Diyala (bassin de celle-ci compris) [1]. Mais l'acquisition d'un bassin hydrographique plus étendu ne correspond plus ici à une extension réelle de la zone d'alimentation, les montagnes drainées par l'Adhaïm et la Diyala sont moins élevées et moins arrosées que celles qui approvisionnent les deux Zab, surtout elles n'interviennent que pour une proportion beaucoup plus faible dans l'ensemble des territoires ajoutés au bassin du Tigre.

Les débits de l'Adhaïm (28 m³/sec.) et même de la Diyala (1.64 m³/sec.) sont tout juste suffisants pour maintenir les débits du Tigre et encore pas tout à fait puisqu'on enregistre déjà une diminution de ceux-ci de l'amont vers l'aval (Samara : 1.254 m³/sec.; Bagdad : 1.236 m³/sec.; Kut : 1.179 m³/sec.).

Les pertes réelles sont d'ailleurs plus fortes que celles que laissent apparaître ces moyennes. Elles sont de 33 m³/sec. à Bagdad [2] et de 221 m³/sec. à Kut [3]. Soit un total de 254 m³/sec. perdus entre Samara et Kut.

Les causes en sont diverses. Tout d'abord, les eaux cheminent plus lentement, la pente ayant faibli à 6,8 cm./km. Le flot qui mettait 52 heures pour aller de Diyarbékir à Mossoul (488 km.), 42 heures pour aller de Mossoul à Samara (292 km.), en met 66 pour parcourir la distance qui sépare Samara de Kut (488 km.). Le fleuve qui a tendance à divaguer de plus en plus offre plus de prise à l'infiltration et à l'évaporation. Cette raison n'est cependant pas la plus importante.

De Balad qui marque son entrée dans le delta jusqu'à Kut, le Tigre coule entre des digues. Si celles-ci sont suffisantes pour contenir ses crues moyennes, elles ne le sont plus dès que le niveau des eaux est trop haut. Il faut alors y pratiquer des brèches, notamment sur la rive gauche du Tigre et à l'amont de Bagdad, afin que la crue puisse s'étaler.

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(1) On ne possède plus de chiffres après le confluent de la Diyala.

(2) Différence entre le débit réel du Tigre à Bagdad et les débits additionnés du Tigre à Samara et de l'Adhaim.

(3) Différence entre le débit réel du Tigre à Kut et les débits additionnés du Tigre à Bagdad et de la Diyala à D. S.

Des inondations ainsi provoquées à une période de l'année où la chaleur est déjà forte, doit résulter une grande déperdition par évaporation.

A ces motifs, s'ajoute l'irrigation qui soustrait de plus en plus d'eau au fur et à mesure qu'on avance de l'amont vers l'aval; le nombre des pompes élevatrices va croissant à l'heure actuelle et la largeur de la région irriguée augmente fortement à l'entrée dans la plaine alluviale.

3. Secteur de dépérissement : de Kut au Chatt el Arab.

Dans la dernière partie de son cours, le Tigre s'effondre littéralement (fig. 13). A Amara, c'est-à-dire à 236 km. de Kut, ce n'est plus qu'une rivière de l'importance de la Diyala; à Qalat Saleh, 47 km. plus bas, il est comparable à l'Adhaïm et aux basses eaux, sa profondeur est moindre que la hauteur d'un homme. Les courbes des débits, si élancées jusque là, se traînent misérablement le long de l'axe des abcisses. En 283 km., on assiste à la mort du fleuve qui jusque là faisait si grande figure. Les débits moyens tombent en effet de 1.179 m³/sec. à Kut, à 218 m³/sec. à Amara et à 78 m³/sec. à Qalat Saleh.

Les hautes eaux se produisent toujours en avril, mai continuant à représenter une moyenne presque semblable. Les basses eaux par contre, sont plus tardives que dans la partie amont du fleuve, elles ont lieu en octobre et non plus en septembre. De même le débit maximum instantané ne s'enrégistre plus jamais avant janvier au plus tôt tandis que le débit minimum a une tendance plus accentuée à se produire en novembre-décembre, ou même en janvier.

Les conditions de vie du fleuve changent complètement dans ce secteur de son cours. Les pentes y deviennent nulles : 3,4 cm./km. (1/29.000ᵉ) puis 1,3 cm./km. (1/76.000ᵉ), la vitesse faiblit dans la même mesure et le flot met 80 heures pour franchir les 450 km. qui séparent Kut de Garmat Ali.

On est en plein ici dans la Mésopotamie des marais. Le Tigre, bordé régulièrement de Bagdad jusqu'à Kut de digues qui le canalisaient et l'empêchaient de se répandre de tous côtés, sauf aux époques de trop hautes eaux, n'a plus ici de digues que sur sa rive droite et encore jusqu'à Sheikh Saad seulement (68 km. à l'aval de Kut). Partout ailleurs

il peut se répandre où bon lui semble et ce n'est que le long du Chatt el Arab que le Tigre, joint à l'Euphrate, coule à nouveau entre des digues.

Il perd donc la plus grande partie de son débit soit par des brèches, soit par des canaux d'irrigation qui alimentent les rizières d'Amara.

Les principaux de ces canaux et de ces brèches sont entre Kut et Amara (fig. 7) :

— la brèche de Mosandak, située sur la rive droite à 85 km. à l'aval de Kut. Elle mène à l'immense marais de Hor el Sanniyah qui s'allonge le long du Tigre à une quinzaine de km. de celui-ci. Elle peut débiter jusqu'à 3.000 m³/sec.

— une autre brèche, située cette fois-ci sur la rive gauche, alimente le marais de Hor el Suwaicha à l'Est de Kut. Son débit maximum est de l'ordre de 640 m³/sec.,

— le canal de Gharraf, juste avant Kut, correspond à un ancien lit du Tigre,

— le canal de Butara sur la rive droite (22 km. avant Amara) peut soustraire à lui seul au fleuve jusqu'à 1.000 m³/sec.,

— les canaux de Musharah et de Chahalah se branchent eux sur la rive gauche juste avant Amara. L'eau qu'ils sont capables de dériver (1.000 m³/sec.) est du même ordre.

Ces proportions établies lors de la crue du 17 mars 1946, montrent que sur les 6.200 m³/sec. qui sont passés alors à Kut, 560 m³/sec. ont seulement gagné Amara. On s'explique facilement dans ces conditions que la perte moyenne annuelle soit de 961 m³/sec. sur les 1.179 m³/sec. qui traversent le barrage de Kut.

Après Amara, des ponctions analogues ont encore lieu. Le Tigre achève de se perdre par des brèches et des canaux dont les principaux sont :

— les canaux Tabar et Majar sur la rive droite à 11 et 21 km. en aval d'Amara.

— le canal Michiriya sur la rive gauche à Qalat Saleh.

Lors de la crue du 17 mars 1946 dont il vient d'être question, il ne parvint à Qalat Saleh que 190 m³/sec. des 560 m³/sec. qui défilèrent encore devant Amara, les 370 autres, se perdirent sur les 47 km. qui

séparent Amara de Qalat Saleh. En année moyenne, la perte, est comme on l'a vu plus haut, de 140 m³/sec.

Le Tigre est donc saigné à mort dans la dernière partie de son cours et perd presque toutes ses eaux dans les champs irrigués et dans les marais. Ces derniers lui en restituent quelquefois une partie à l'époque des basses eaux mais cette fraction est faible et ne soutient que bien peu ses débits.

Il en est de même des rivières venues de Perse dont la principale est la Kerkha. Celle-ci avec un bassin de 38.700 km² a un débit moyen annuel de 220 m³/sec. Elle rejoint le Tigre à Madik un peu à l'amont de la localité d'Azir (située elle-même à l'aval de Qalat Saleh) mais elle ne lui parvient qu'à travers toute une zone de marécages où elle s'épuise de telle sorte que l'apport réel qu'elle fournit au Tigre doit en être gravement diminué.

II. L'EUPHRATE [1].

L'étude de l'Euphrate est plus difficile à mener que celle du Tigre. En effet à la différence de celui-ci dont le cours se déroule presque tout entier en Irak, le sien se développe pour plus de la moitié en Turquie et en Syrie, pays pour lesquels les données hydrologiques sont encore inexistantes ou non publiées.

L'Euphrate est un fleuve très long. Depuis le confluent du Kara Sou et du Murat Sou qui mesurent déjà respectivement 450 et 650 km., il n'atteint pas moins de 2.333 km. jusqu'à Bassora alors que le Tigre depuis Diyarbékir n'en avait que 1.718.

En Irak, les principales stations de jaugeage sont situées à Ana, Hit, Ramadi, Hindiya, Shinafiya et Nasiriya. Elles permettent de se faire une idée déjà assez précise de son régime dans son parcours irakien. Il ne sera question ici que de ce secteur, l'étude du fleuve dans son ensemble restant à faire.

1° Les Facteurs du Régime.

Ils ne sont connus que dans leurs grandes lignes, surtout en ce qui concerne la climatologie.

[1] Voir les ouvrages cités à la note 15, auxquels il faut ajouter : Ahmed Sousa, *The Euphrates* (1 vol. et 1 atlas) Bagdad, 1944.

A. *Nature et relief du sol.*

Comme le Tigre, l'Euphrate est composé essentiellement d'un bassin montagneux où il s'alimente et d'un bassin en plaine qu'il traverse en étranger.

1. Dessin, altitude et superficie du bassin hydrographique (tableau n° XII).

TABLEAU N° XII : BASSIN DE L'EUPHRATE.

(*Superficie en Km²*)

Kara sou (au confl. avec le Murat sou)	21.500
Murat sou (au confl. avec le Kara sou)	39.700
Euphrate, à Keban (confl. du K.S. et du M.S.)	61.200
— à Djerablous	96.000
— à Rakka	129.100
— à Deir ez Zor	142.700
— à Ana	229.400
— à Hit	264.120
— à Ramadi	267.300
— à el Musayib	274.100
— à l'embouchure	444.000
A Hit, le bassin se décompose de la manière suivante :	
Montagnes	82.330
Collines	62.960
Région désertique	118.830

Le bassin montagneux de l'Euphrate n'est plus comme celui du Tigre une longue façade escarpée orientée Ouest-Est puis Nord-Ouest-Sud Est mais une sorte de haut plateau : l'ancienne Arménie, qui épouse grossièrement une forme rectangulaire (fig. 3). Celui-ci est limité au Nord par les chaînes du Pont drainées vers la mer Noire, au Sud par le Taurus arménien, à l'Ouest par le Taurus cilicien et l'Anti-Taurus qui le prolonge, à l'Est enfin par les hautes montagnes qui séparent la Turquie de la Perse et dont l'Araxe et le bassin fermé du lac de Van se sont d'ailleurs annexés une grande partie.

Deux grandes rivières d'orientation Est-Ouest donnent naissance à l'Euphrate. La première, *le Kara Sou* (450 km.) constitue la grande voie de communication qui par Erzindjian et Erzeroum donne accès à la Transcaucasie et à l'Azerbeïdjan persan. Elle draine un bassin restreint (21.500 km²), des chaînes élevées bordant celui-ci immédiatement de part et d'autre de la rivière. Les altitudes sont fortes : 2.000 m., souvent 2.500 m., parfois 3.000 m., le point culminant atteignant 3.288 m. dans le Kargapazari Dagh.

La seconde, *le Murat Sou* (650 km.) lui est parallèle à une centaine de km. plus au sud. Sa zone de drainage est beaucoup plus étendue (39.700 km²) et s'étend à la région la plus tabulaire de l'Arménie mais encore assez élevée : 1.000-1.500 m. à l'Ouest, 1.500-2.000 m. au centre et à l'Est. A la différence du Kara Sou qui était à peu près sans affluents, elle reçoit sur sa droite toute une série de rivières importantes.

A eux deux, le Kara Sou et le Murat Sou (61.200 km²) *forment près des deux tiers du bassin d'alimentation de l'Euphrate. Le dernier tiers est formé par des rivières qu'il reçoit sur sa droite et qui lui viennent de la prolongation du Taurus cilicien* dont elles drainent le revers Sud-Est (1.500 à 2.000 m. d'altitude).

Après les avoir reçues, l'Euphrate débouche par une série de gorges sur la Djéziré et sort définitivement de la montagne, c'est-à-dire de sa zone d'alimentation qui peut être évaluée à 82.330 km².

Il s'enfonce alors dans une région où les pluies deviennent de plus en plus rares. Deux affluents : *le Balikh et le Khabour,* lui arrivent encore sur sa gauche. Mais ni l'un ni l'autre, nés tous les deux dans le piedmont du Taurus arménien, ne lui apportent un appoint d'eau appréciable.

Très vite, l'Euphrate n'est donc plus qu'une artère d'évacuation des eaux reçues en Turquie et se trouve être par conséquent complètement étranger au désert qu'il traverse. Son bassin dans cette région est cependant immense et ne cesse de croître. De 96.000 km² à Djerablous, il est de 444.000 km² à son embouchure. Il englobe en effet une très vaste partie du désert de Syrie d'où lui arrivaient au Quaternaire des rivières de plusieurs centaines de km., réduites à l'heure actuelle à la condition d'oued misérables.

Les bassins du Tigre et de l'Euphrate ont donc en commun d'être formés d'une double partie : l'une montagneuse où ils s'alimentent, l'autre plane qu'ils ne font que traverser. La disposition n'est toutefois pas la même de part et d'autre. Le Tigre reste parallèle à la façade d'où lui viennent ses eaux, ses affluents le soutiennent au fur et à mesure qu'il s'épuise et cela jusqu'à la latitude de Kut qui est déjà assez basse. L'Euphrate au contraire a un bassin d'alimentation beaucoup plus concentré et situé tout entier au Nord de celui du Tigre ; à la sortie du Taurus arménien, il est en possession de toutes ses eaux alors que le Tigre ne fait que commencer à collecter les siennes ; aucun affluent digne de ce nom ne viendra le soutenir par la suite. C'est dans ces conditions qu'il doit parcourir les 1.980 km. qui séparent Djérablous de la mer tandis que le Tigre est encore soutenu à moins de 1.000 km. de celle-ci par l'apport de la Diyala.

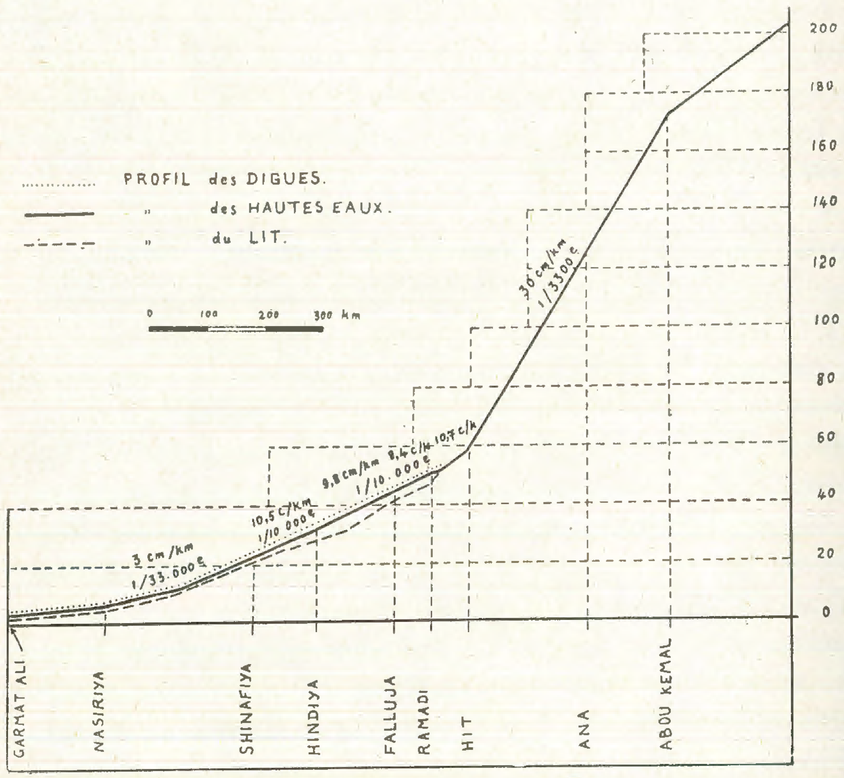


Fig. 17. — Profil longitudinal de l'Euphrate.

2. LES PENTES (figure 17 et tableau n° XIII).

Moins favorisé que le Tigre du côté de son bassin, l'Euphrate l'est relativement un peu plus du côté des pentes.

TABLEAU N° XIII : DISTANCES ET PENTES DE L'EUPHRATE.

	Distances de l'aval à l'amont	Distances de l'amont à l'aval	Niveau moyen		Pente cm./km.	Vitesse d'écoulement
			Hautes eaux	Basses eaux		
Keban (Confl. K. S. et M. S.)	2.433	0	—	—	—	—
Djerablous	1.980	453	370			—
Rakka	1.754	679	—	—	31	—
Deir ez Zor	1.530	903	230			
					30	2J.3H.
Ana	1.173	1.260	125			
					30	1J.6H.
Hit	953	1.480	55,35	52,69		
					10,7	16H.
Ramadi	890	1.543	48,57	45,85		
					8,4	19H.
Falluja	818	1.615	42,60	39,64		
					9,8	1J.10H.
Hindiya	683	1.750	29,81	25,93		
					10,5	3J.2H.
Shinafiya	525	1,908	14,01	8,52		
					3	6J.12H.
Nasiriya	273	2.160	4,38	2,55		
Bassora	100	2.333	—	—	—	—
Embouchure	0	2.433	—	—	—	—
	Sousa	Sousa	Ionides	Ionides		Ionides

Longueur approximative du Kara Sou : 450 km.
Longueur approximative du Murat Sou : 650 km.

Durant toute la traversée de la Djéziré, c'est-à-dire de Djerablous à Hit (1.027 km.), il possède une déclivité de 30 cm. par km. qui lui assure un écoulement rapide.

Une fois entré dans le delta, cette inclinaison faiblit mais beaucoup moins brusquement que celle du Tigre. Elle reste de l'ordre de 9 à 10 cm. par km. jusqu'à Shinafiya qui se trouve à peu près à hauteur de Kut (10,7 cm./km. entre Hit et Ramadi; 8,4 cm./km. de Ramadi à Falluja; 9,8 de Falluja à Hindiya; 10,5 de Hindiya à Shinafiya). *Dans toute la Mésopotamie septentrionale, l'Euphrate coule donc légèrement plus haut que le Tigre* [1] de telle sorte que la plaine qui les sépare est irriguée par des canaux qui sont branchés sur lui et qui divergent en direction du Tigre.

Ce n'est qu'après Shinafiya que la pente s'effondre et tombe à 3 cm./km., déclivité plus faible que celle qui existe entre Kut et le Chatt el Arab (3,4 cm./km.) de telle sorte que la situation est ici inversée et que les eaux qui s'épandent dans la Mésopotamie méridionale proviennent plus du Tigre que de l'Euphrate.

B. *Climatologie* [2].

La pluviosité de la Turquie orientale qui alimente l'Euphrate est très mal connue.

D'une manière générale cependant, la hauteur des pluies peut être estimée à une tranche d'eau de 400 à 600 mm. d'épaisseur sauf dans la vallée de l'Euphrate entre Erzindjian et Malatia où elle tombe au-dessous de cette valeur (Malatia : 372 mm.; Erzindjian : 313 mm.).

Les hautes chaînes, et elles sont nombreuses dans le bassin du haut Euphrate, doivent recevoir des précipitations beaucoup plus fortes, équivalentes sans doute à celles du Kurdistan. En de nombreux points, elles doivent atteindre 1.000 mm. et même les dépasser.

Enfin l'Arménie située beaucoup plus au Nord que le Zagros qui alimente le Tigre, d'une altitude moyenne beaucoup plus élevée, laisse prévoir aussi que ces précipitations y tombent principalement sous

[1] Comparer les tableaux V et XIII. [2] Voir tableau n° VII et carte d'Ashbel.

forme de neige. L'analyse du régime de l'Euphrate permet à elle seule d'en apporter une confirmation décisive.

2° Le Régime.

On reprendra ici pour sa description les cadres qui ont déjà servi pour celle du Tigre.

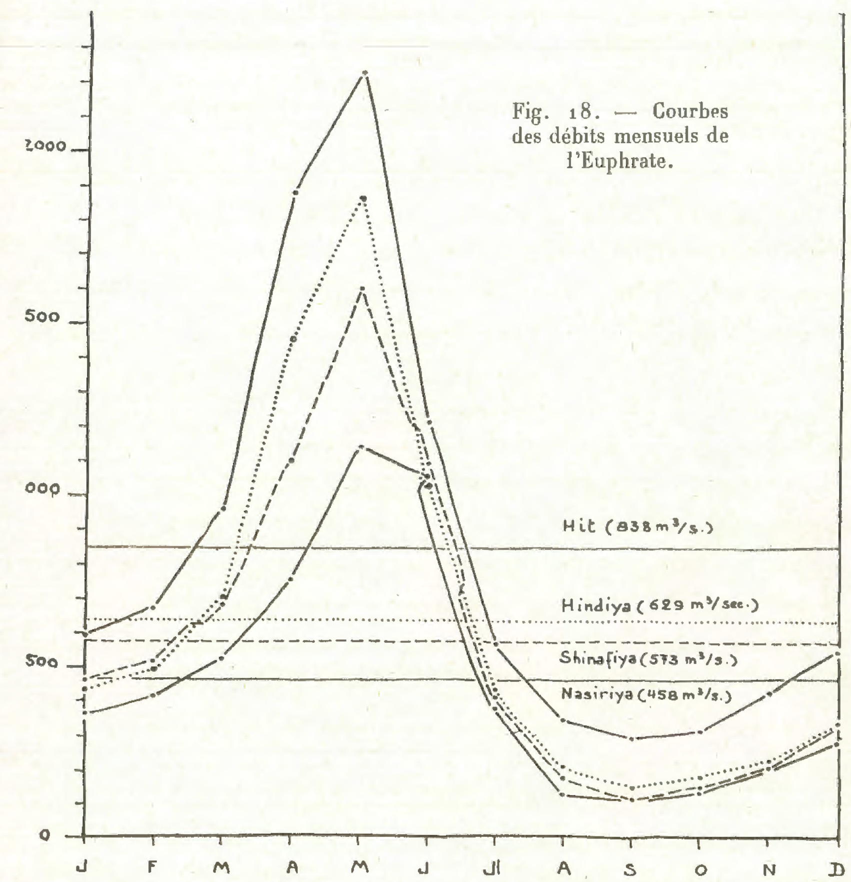


Fig. 18. — Courbes des débits mensuels de l'Euphrate.

A. *Variations dans le temps.*

Elles sont presque en tous points semblables à celles du Tigre.

1. Variations saisonnières (figure 18 et tableau n° XIV).

TABLEAU N° XIV : DÉBITS MOYENS DE L'EUPHRATE.

	Sources	J.	F.	M.	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	Moyenne annuelle	Crue Maximum		Etiage Minimum	
															Date	Débit	Date	Débit
(1) à Hit (1924-1951)	D.B.	587	668	962	1.880	2.230	1.210	567	354	**293**	317	433	547	838	5.5.29	5.200	6.9.30	181
(2) à Hindiya (1923-1948)	H.	433	492	705	1.454	1.861	1.037	436	214	**155**	182	233	343	629	24.4.41	2.880	—	0
(3) à Shinafiya (1929-1948)......	H.	453	515	688	1.097	1.600	1.089	426	183	**119**	150	213	337	573	13.5.48	2.137	20.12.30	3
(4) à Nasiriya (1926-1948)	H.	363	411	522	747	1.138	1.051	380	132	**117**	146	207	283	458	25.5.48	1.740	11.9.35	40

Elles se caractérisent aussi par un étiage de saison chaude, une montée d'automne et d'hiver, des hautes eaux de printemps.

a. Etiage de saison chaude. — *Il se produit partout, depuis la frontière de Syrie jusqu'au Chatt el Arab, durant le mois de septembre*. Pratiquement il est atteint dès le mois d'août et se prolonge jusqu'en octobre.

Comme pour le Tigre, la fin de l'été et le début de l'automne sont la grande époque du dépérissement. Les précipitations d'hiver ont été alors complètement évacuées, les quelques réserves souterraines sont taries, la chaleur estivale a exercé son maximum d'effet évaporant et les irrigations ont largement prélevé leur part du débit de l'Euphrate. Dans ces conditions, celui-ci tombe au tiers de son module dès Hit, au quart ou au cinquième après Hindiya.

b. Montée d'automne et d'hiver. — *La montée des eaux amorcée dès novembre est par contre beaucoup plus lente ici que pour le Tigre*. On a vu pour celui-ci que le débit moyen de février était déjà supérieur au module annuel et que pour ses affluents à l'exception du Grand Zab ce passage s'opérait dès janvier. Sur l'Euphrate au contraire, le débit moyen mensuel reste nettement au-dessous du module en février et ce n'est qu'en mars qu'il commence à le dépasser.

Les rétentions nivales s'avèrent donc déjà beaucoup plus importantes sur l'Euphrate que sur le Tigre.

c. Hautes eaux de printemps. — *Ces rétentions deviennent tout à fait évidentes quand on considère l'époque où se produisent les hautes eaux. Avril*

est le mois de la crue, mai lui est cependant encore supérieur. Ce mois manifeste même une accentuation notable de la montée des eaux alors que sur le grand Zab il montrait bien une moyenne supérieure à celle d'avril mais de manière insignifiante.

Il n'y a donc aucune espèce de doute que le régime de l'Euphrate est beaucoup plus en dépendance des eaux de fonte des neiges que de l'écoulement des pluies d'hiver.

La décrue est rapide. Comme pour le Tigre, si juin est encore au-dessus du module, juillet est déjà fixé au-dessous.

Ce n'est cependant qu'en août que le fleuve s'appauvrit réellement.

2. VARIATIONS ANNUELLES (figure 16 et tableau n° XV).

L'observation des variations entre les débits moyens annuels du Tigre et de ses affluents (tableau n° X) a déjà permis de voir que ces variations étaient absolument synchronisées. Les courbes montrent en outre que les débits sont très variables. Entre 1920 et 1951, le Tigre à Bagdad dont le module pour l'ensemble de ces années est de 1236 m³/sec. a vu passer son débit moyen à 1.670 m³/sec. en 1946 alors qu'il n'avait été que de 499 m³/sec. en 1930. Dans un cas, le débit a été 1,3 plus fort que la normale alors que dans l'autre il n'en représentait qu'une fraction égale à 0,4 ; le rapport entre les débits extrêmes étant plus grand que 3 à 1.

TABLEAU N° XV : VARIATION DES DEBITS ANNUELS DE L'EUPHRATE.

	à Hit	à Hindiya	à Shinafiya	à Nasiriya
1923...	—	**577**	—	—
1924...	**718**	639	—	—
1925...	**526**	**392**	—	—
1926...	906	815	—	626
1927...	**527**	**427**	—	**364**
1928...	**621**	**436**	—	**319**
1929...	1.030	768	645	536
1930...	**382**	**240**	**197**	**163**
1931...	**767**	644	**488**	**413**
1932...	**536**	**397**	**308**	**280**
1933...	**484**	**325**	**221**	**218**
1934...	**563**	**398**	**341**	**291**
1935...	1.010	752	645	537
1936...	994	783	721	636
1937...	881	**622**	**508**	**419**
1938...	1.070	787	700	545
1939...	941	670	**547**	487
1940...	1.110	855	755	619
1941...	1.140	899	759	561
1942...	1.100	774	675	484
1943...	1.020	722	675	507
1944...	1.090	779	678	522
1945...	867	**591**	586	**452**
1946...	1.060	743	679	573
1947...	**779**	**561**	574	**429**
1948...	1.130	750	749	554
1949...	**710**	—	—	—
1950...	**794**	—	—	—
1951...	**689**	—	—	—
Moyenne	838	629	573	458
	D. B.	Haigh	Haigh	Haigh

L'Euphrate montre des phénomènes semblables. *La courbe des variations des débits annuels à Hit qui est le prototype de toutes les autres, révèle les mêmes séries d'années de suralimentation ou de sous-alimentation que les courbes du Tigre et de ses affluents.* Si ce synchronisme était déjà intéressant à noter entre celles-ci, il l'est encore plus dans ce dernier cas. Il révèle en effet que les variations des précipitations en Arménie sont les mêmes que dans le Kurdistan et le Zagros. Le fait à première vue pouvait paraître probable mais que le parallélisme soit aussi étroit ne laisse pas que d'étonner un peu quand on se souvient de la différence de configuration des bassins du Tigre et de l'Euphrate et surtout de leur position en latitude.

Les écarts eux aussi sont équivalents. A Hit, le module des années 1924-1951 est de 838 m^3/sec. Le plus fort débit moyen annuel a été observé en 1941 où il s'est élevé à 1.140 m^3/sec. tandis que le plus faible en 1930 s'était abaissé à 382 m^3/sec. Les coefficients respectifs par rapport à la normale sont donc de 1,3 et 0,45. Ce sont ceux du Tigre à Bagdad.

B. *Abondance moyenne.*

Déjà plus indigent que le Tigre sous l'angle du module, le sien n'atteignant que les deux tiers de celui-ci (838 et 1236), l'Euphrate l'est encore de manière beaucoup plus accentuée sous le rapport du module relatif.

A Hit, son bassin est de 264.120 km^2 sur lesquels 118.830 km^2 sont désertiques. Par suite le module relatif est très bas : 3,1 l./sec./km^2 et s'apparente aux modules les plus bas du bassin du Tigre (Diyala : 5,5 l.; Adhaïm : 2,8 l.). Il dénote un indice d'écoulement très faible, moins de 100 mm., exactement 97,8 mm.

Si l'on estime [1], l'indice de pluviosité à 450 mm., le coefficient d'écoulement ne représenterait que 0,22 des pluies tombées sur l'ensemble du bassin.

C. *Variations du fleuve d'amont en aval.*

Les variations de l'Euphrate dans son parcours irakien présentent beaucoup moins de diversité que celles du Tigre. Celui-ci comportait

[1] Cf. Ionides.

comme on l'a vu, un secteur de croissance, un secteur d'écoulement où pertes et gains se compensaient, un secteur de dépérissement. Ces secteurs, au moins le premier et le dernier, doivent exister aussi sur l'Euphrate. *Son cours entre la frontière syrienne, et sans doute dès la frontière turque, se localise cependant tout entier dans le dernier.*

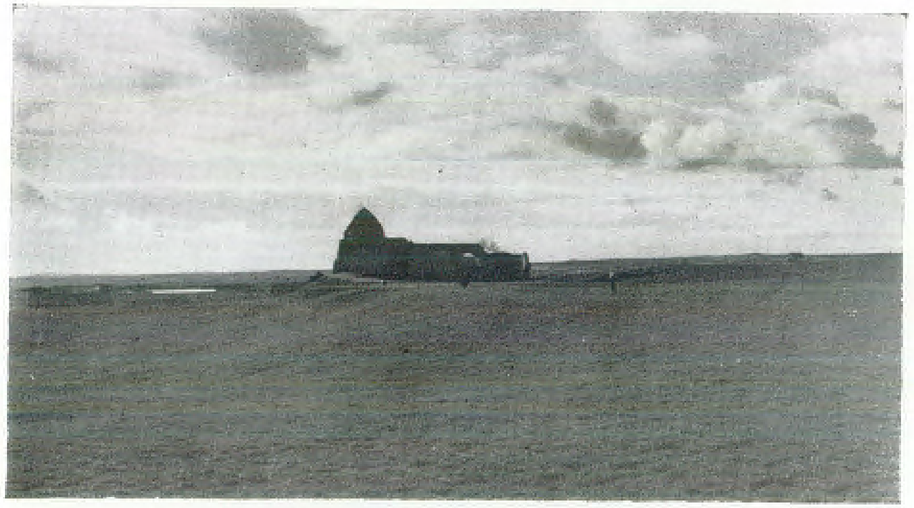
Un simple examen des courbes (fig. 18) suffit à le montrer. Plus on va vers l'aval et plus elles perdent de hauteur ; le module passant successivement de 838 m^3/sec. à Hit, à 629 à Hindiya, 573 à Shinafiya, 458 à Nasiriya. Sur les 680 km. qui séparent Hit de Nasiriya, l'Euphrate perd 46 % de son débit qui lui est soustrait par l'évaporation et par les canaux d'irrigation.

A la sortie du lac Hammar dans lequel il va se perdre après Nasiriya, c'est certainement à plus de la moitié du module qu'il avait en entrant dans le delta que doivent se chiffrer ses pertes. Comme le Tigre, il ne fournit plus au Chatt el Arab que des eaux extrêmement appauvries. A la différence de celui-ci cependant qui s'effondrait presque d'un seul coup après Kut, son dépérissement se fait de façon beaucoup plus progressive comme le montre suffisamment la comparaison des figures 13 et 18.

Quant aux crues, elles suivent une décroissance semblable. La plus forte qui ait été enregistrée à Hit totalisait 5.200 m^3/sec. tandis que les chiffres maxima sont respectivement pour Hindiya, Shinafiya et Nasiriya de 2.880, 2.137 et 1.740. Capables de sextupler le module à Hit, elles ne font plus que le tripler à Nasiriya.

A. Le Tigre à Mossoul.

La photographie est prise vers l'amont. Le fleuve n'est pas encore à l'époque où les eaux sont les plus hautes. Le débit est déjà cependant assez fort et le courant rapide (19 février 1947).



B. La Djéziré aux environs de Mossoul.

Paysage très légèrement vallonné, caractéristique de cette région. Ciel nuageux d'hiver (19 février 1947).

Clichés E. de Vaumas.

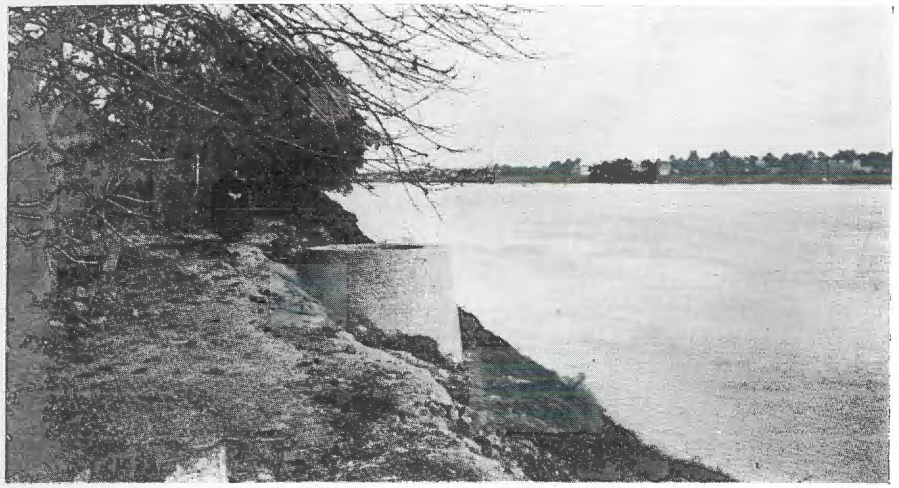
A. L'Euphrate à Koufa.

Il s'agit ici seulement du bras qui passe aux environs de la ville sainte de Nedjef. Rivière tranquille. Berges très basses. Palmeraies (17 février 1947).

B. Cuvette du lac de Habbaniyé.

Le lac est dans le fond, invisible. Paysage typique de l'Irak méridional : étendue sans fin où aucun relief ne se distingue à l'œil nu. Au premier plan, tentes et huttes de claies et de roseaux servant aux nomades qui se déplacent selon les fluctuations du lac (23 septembre 1954).

Clichés E. de Vaumas.



A. Le Tigre un peu en aval de Bagdad.

Le fleuve est en période de montée. A gauche, digue (8 janvier 1947).

B. Affluent de la Diyala à Khanikin.

Rivière venant du Zagros tout proche. Brouillard matinal, la photographie est prise peu après le lever du soleil (9 janvier 1947).

Clichés E. de Vaumas.

A. Le désert aux environs de Rutba.

Couches crétacées disséquées. Entablements et buttes. Très grande aridité du paysage (22 septembre 1954).

B. Le Chatt el Arab à Bassora.

La photographie est prise vers l'amont. L'importance du fleuve affecté par la marée du golfe Persique a permis d'y aménager un port par où se fait tout le trafic maritime de l'Irak.

Clichés E. de Vaumas.

THE CLIMATES OF IRAN

BY

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Chapter I

PHYSICAL BACKGROUND

The relief map of Asia shows that the continent consists of four major series of physiographic units. The first series includes the great southern peninsulas, the second consists of a broad mountain belt, the third is formed by a number of massives and, the fourth comprises the northern plains, steppes and tundras, which separate the massives from the Arctic Ocean.

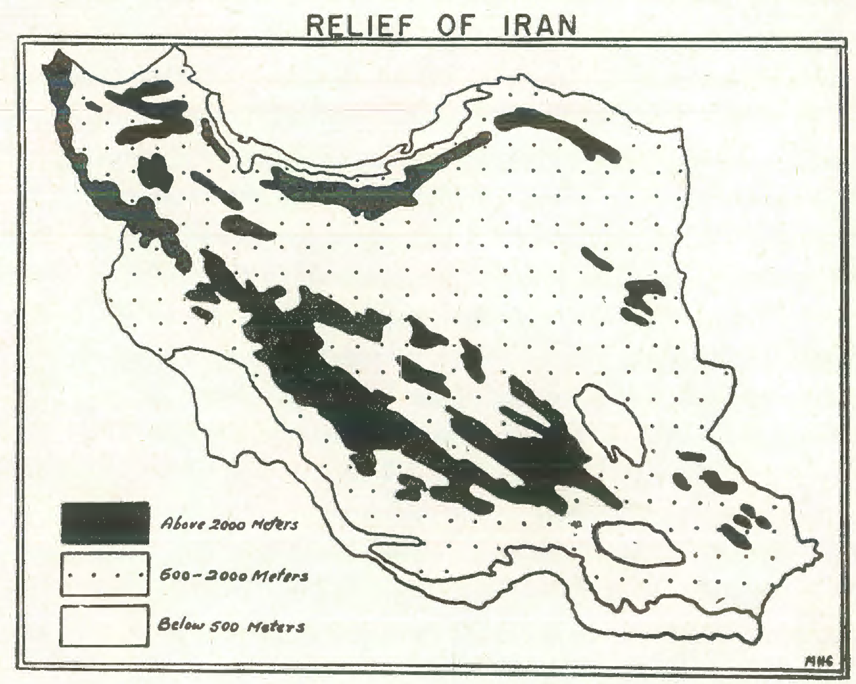
The mountain belt of Asia, generally referred to as the Alpine-Himalayan system, occupies a large part of the eastern side of the continent but somewhat tapers in the west, especially at the Armenian Knot, where several Asiatic ranges unite.

Between the Armenian Knot in the west and the Pamirs in the east, stretches a great plateau, occupied by the states of Iran and Afghanistan and known to the geographers as the Plateau of Iran. Its shape is an irregular rectangle. It extends in its greater length, which is from west to east, for not less than thirty degrees of longitude (44° to 74° E.) or about 2,700 km., while its breadth from north to south varies from ten degrees latitude along the line of Zagros, to more than twelve (25° to 38° N.) where it meets the Indus valley. Situated between this fertile valley in the east and the agricultural lands of the Tigris in the west, the plateau of Iran (about 1,000,000 square miles in area) is bounded on its northern side by the steppes of southern Turkistan, the Caspian Sea and the Caucasus ranges, while the Sea of Oman and the Persian Gulf can be considered its southern limits.

Within the limits laid down above, the Iranian plateau is divided into two unequal parts by a series of broken highlands that run almost along the line of 60° E. longitude which coincide with the political frontier between Iran and Afghanistan and, at the same time, separate the depressions of central Iran from the more elevated deserts of Afghanistan. It is with the larger section of this plateau, located to the west of this dividing line, namely the kingdom of Iran, that we are

concerned throughout the present study and the term «Iranian plateau» or «plateau», whenever used in the following pages should be strictly applied to the western section in particular and not to the plateau of Iran as a whole.

A glance at the relief map of Iran (map No. 1) would, at once, reveal the plateau and mountainous nature of the country. The mountains



Map No. 1 : Relief of Iran.

show a considerable concentration in the western and northern sections, where they form continuous and almost unbroken belts.

Another striking feature of the relief map under consideration is the almost complete lack of lowland plains, especially along the sea shores, where the mountain slopes, or the escarpments of the plateau, reach the seas without the intervention of extensive coastal plains. This is particularly the case in the northern sections of the country where the narrow plains of the southern Caspian Sea do not average more than fifty kms. in width. The only exception to the rule, however, is to be found in the low

delta plain of Karun River, better known as the oil province of Khuzistan, at the head of the Persian Gulf. This is, in reality, an extension of the Mesopotamian lowlands to the west with which the Iranian section has many physiographical features in common.

The interior of Iran is characterized by lower altitude and more uniform relief than the western or northern sections. This is the desert part of the country, occupied by the terryfying and extensive wastelands of Kavir to the north and the Dasht-e-Lut to the south.

Iran is thus a high plateau ringed on all sides by higher mountains which, in the words of W. B. Fisher, give the country a marked unity based on separation from its adjoining regions [1]. In addition to giving the country its unity, these mountains play an important part in the climatology of the country as will be seen in the following chapters. It is therefore appropriate to pay some attention to the mountain rim of the country and to the associated highlands that, by virtue of their geographical layout, play a decisive role in producing a great diversity of climates in different sections of the Iranian territory.

Generally speaking, there are two major mountain systems of different character in Iran. These are the Alborz, running almost from west to east, and the Zagros, extending from northwest to southeast. The two systems, like a few more of the Asiatic mountain ranges, meet at the Armenian Knot or the great mountain junction of Armenia. This, therefore, appears to be a convenient point for starting the very brief discussion of the orography of Iran.

From the picturesque and snow clad volcanic cone of Ararat (5,156 m. high) in Armenia, the two mountain systems of Iran branch off in the directions just indicated above and in such a way as to form a rim of higher land along the northern and western peripheries. The first of the two systems, namely the Alborz, and its associate ranges form a continuous wall along northern Iran from Ararat in the northwest corner to Sarakhs in the northeast corner of the country.

The Alborz system consists of three parallel ranges, increasing in elevation from north and south, representing on the southern flank an

(1) Fisher (W. B.), *The Middle East,* London 1950, p. 255.

abrupt escarp which rises to 3,870 m. in Towchal, only a few kilometers to the north of the capital. The ranges are separated from each other by narrow longitudinal valleys that offer no entry to the interior of the country except along a limited number of passes such as the Sefid-Rud and Haraz valleys. In the middle range of the Alborz is found the famous Mount Demavand, the highest peak in Iran with an elevation from 5,465 to 6,559 m. [1].

The Zagros system begins with the Turkish frontier ranges which are, in reality, the eastern escarpments of the Anatolian plateau. The frontier ranges form an important climatic barrier, as will be seen later in the present study and therefore need careful attention. They extend in a north to south direction between Ararat and the southwestern parts of the Lake Rezaiyeh (also known as Lake Shahi or Urmia). At the termination of the frontier ranges begins the main Zagros system which consists of a number of ranges running from northwest to southeast, almost parallel with one another. They form an unbroken and impenetrable wall of mountains, about 1,000 km. in length and often more than 200 km. wide [2]. They attain heights of over 4.500 m. and therefore play an important part in the climatology of the country.

Before reaching Khuzistan, the Zagros mountains assume a southeasterly direction and run through the two extensive provinces of Fars and Kerman. Here their general trend is in parallelism with the nearby coastlines of the Persian Gulf and the Sea of Oman.

Beside the two major mountain systems, briefly described above, there are in Iran a number of independent mountain ranges, running in all directions; most important among them are the Central Ranges that begin to the south of Azarbaijan and run parallel with the main Zagros system. Running almost unbrokenly for 1,300 km. between Azarbaijan in the northwest and Baluchistan in the southeast, this series with peaks that reach heights of over 4,400 m., forms a prominent relief feature of Iran. It separates the fertile and well populated valleys and basins,

(1) Blanchard (R.), *Asie occidentale,* vol. 8 of the *Géographie universelle,* Paris 1929, p. 138.
(2) Blanchard (R.), *op. cit.,* p. 129.

such as those of Isfahan and Sirjan, lying to its west, from the wide expanses of desolate desert to the east.

From the above description of the mountains of Iran it is clearly seen that the country is surrounded by mountain ranges on all sides and this gives it a basin character in spite of the fact that it has been described as a plateau. The immediate result of the arrangement of mountains in the marginal areas is that more than half of the country's surface loses its waters in the interior. However, the complete absence of any river of considerable size on the map of Iran is a striking feature, indicating the degree of aridity prevailing in Iran. The number of perennial rivers that drain the interior of the country hardly reaches half a dozen and even these dwindle to simple brooks or disappear altogether during the hot summer months.

Generally speaking, five major drainage zones can be recognized in Iran with the following approximate areas :

1 : The Interior	900,000 sq. kil.
2 : The Caspian Sea	250,000 —
3 : The Persian Gulf & The Sea of Oman	350,000 —
4 : The Lake Rezaiyeh	40,000 —
5 : The Seistan Depression	100,000 —
Total area	1,640,000 sq. kil.

The interior of Iran is very dry but, nevertheless, during the short rainy season, river beds are flooded and torrential currents rush down hurriedly towards the internal basins and salt wastes into which they eventually disappear. In this season they cause heavy erosion and produce extensive gravel slopes and fans all along the foothills. It is on such gravel slopes that towns and villages of Iran are usually situated.

Over the wide extent of desert which occupies most of the central Iran, small streams of various sizes flow with a general inward direction. However, it should be noted that a great majority of such streams shown on the physiographic maps of the country are nothing but dry valleys that accomodate the rain waters a short period only, which in some parts may not exceed a few days a year.

Of the south flowing rivers that take their sources in the Alborz ranges, the two important ones are Karaj and Jajerud, some 40 km. to the west and east of Tehran respectively.

Of the other rivers that flow into the interior from the Alborz, none is perennial or worthy of name. Their waters are brackish without exception and they disappear into salt swamps, lakes or deserts further to the south.

By far the most important river of the interior of Iran is Zayendeh Rud, rising in the Zard-Kuh (Yellow Mountain) in the eastern Zagros group. The river follows an easterly course to the fertile and prosperous basin of Isfahan where it gives life to one of the most populous districts of central Iran. Its waters are utilized to the last drop and it is only during the spring and winter months that some of its waters reach the Gavkhooni swamp into which the river is lost.

The Caspian littoral is a narrow coastal plain, with an average width of about 50 km. uncovered by the gradual retreat of the sea, which at one time, extended as far south as the foot of the Alborz mountains. Numerous rivers festoon the northern foothills of the Alborz but they are all short and cover small distances before they reach the sea. There are, however, four rivers of considerable importance that have their sources in the distant regions and empty their waters in the Caspian after covering considerable distances. They are, in order of importance and from west to east, Aras (Araxes), Sefid-Rud (White River), Gorgan and Atrak.

The streams that drain some 350,000 sq. km. of territory to the west and south of Iran, diminish in importance from northwest to southeast. They are, in this respect, a good reflection of the climatic conditions prevailing in the western and southern parts of Iran, as will be seen in the future chapters. The western slopes of the Zagros are among the better favoured regions of Iran and receive considerable precipitation during the winter season. They pour their waters into great rivers, that after passing through tortuous but picturesque valleys, join the Tigris or Shat-al-Arab. Of these two, namely Karkheh and Karun deserve special mention because of their greater size and economic importance.

By far the most important river of Iran and the only one navigable to commercial vessels, is the river Karun which starts in the Zard-Kuh,

where a distance of a few miles separate it from Zayendeh-Rud. Here during the past few years a gigantic hydroelectric project has diverted the waters of this river to the interior of the country through the course of Zayendeh-Rud.

In its northern section, Karun has a most tortuous course and flows in various directions through the mountains. It has been calculated that the distance from Kuh-e-Rang, where the hydroelectric plant is installed, to Shushtar, is only 75 miles as the crow flies, but, the distance travelled by Karun between these two points is no less than 250 miles with an aggregate fall of 9,000 feet [1]. The Karun, which after its junction with the Dezful River becomes a wide and deep stream, continues its course towards the united waters of Euphrates and Tigris, known as Shat-al-Arab, to within a distance of three to four miles from that great estuary and about 35 miles from its mouth.

Leaving the plain of Khuzistan and following the coast of the Persian Gulf southeastward, one encounters no river of importance. Aridity prevails everywhere as will be seen later and, consequently, there is only a number of brackish rivers among which may be named the Dalaki, Minab and Rud-e-Shur.

Of the total area of the large province of Azarbaijan, about 40,500 sq. km. are drained into the lake Rezaiyeh which is the largest permanent salt water lake of Iran. The lake is situated at an elevation of 1,200 m. above sea level. It receives 14 small rivers from all sides mostly brackish in character. The lake itself is drying up rapidly due to excessive evaporation and its shallowness. It has an average depth of about five meters and its waters are so brackish that it is not possible to dive in it, because of the considerable proportion of its salt content.

In eastern Iran there is another important hydrographic basin, known as the Hamun Lake or the Seistan Depression. The basin includes only 100,000 sq. km. of Iranian territory but, it is responsible for the drainage of the whole of the neighboring country of Afghanistan. There is practically one major river system in the entire basin and that is the

[1] Bishop (M.), *Journeys in Persia and Kurdistan*, vol. 1, London 1891, p. 30.

Hirmand (also spelt Helmand by European geographers) which has its sources at the foot of the Hindukosh mountains. The river, however, receives countless tributaries, during the rainy season, through which it drains a greater part of central and western Afghanistan into the alluvial and fertile plain of Seistan.

Unlike Hirmand, which is one of the most bountiful rivers of the Iranian plateau, the streams that drain only a small portion of the Iranian territory into the basin, are simply dry beds which can be occasionally innundated during the spring floods.

Finally mention must be made of another river, namely Hari Rud in N. E. Khorassan which drains a small section of the Iranian territory into the Kara-Qum (Black Sand) basin in Russian Turkistan.

Chapter II

SURVEY AND EVALUATION OF DATA

The first climatic studies in Iran were carried out either by foreign travellers who spent some time in the country or by members of the foreign diplomatic services resident there. Most important among the latter group were the British Consular Agencies which, at one time, were well distributed all over Iran. *Unfortunately, the data collected by such agencies were seldom published or made available for any systematic study. In most cases neither the observers, nor the officials in charge, had the necessary background or interest for such a task, but the information so gathered was of great value during the first World War when the British and the allied troops had to cross the country.* This type of information is partly embodied in the Encyclopedia Britanica and in some of the other official British publications [1].

Considered most important among the climatic studies carried out in the neighboring countries are those of the Indian Meteorological

[1] *Encyclopedia Britanica,* 11th edition, 1911, vol. 21, pp. 190-191. Great Britain, Hydrographic Office, « Persian Gulf Pilot », 9th edition, London 1942. Great Britain, Admiralty, Naval Intelligence Division, « Persia », Oxford 1945.

Department, whose bulletins and memoirs contain valuable material. Ever since its inauguration in 1875, this Department took a great interest in the study of climate of the countries adjoining India and its efforts, in the case of Iran, brought forth a work of considerable importance by its former director B. N. Banerji, entitled « The Meteorology of the Persian Gulf » [1].

Climatic studies on Iraq are not as extensive as those of India, but nevertheless, there are useful publications containing valuable information about some Iranian stations. « The Climate and Weather of Iraq » by W. B. Normand, for instance, includes temperature and rainfall data for some half a dozen Iranian stations [2]. The work of Dr. Hans Boesch, based on the observational material of the Iraq Petroleum Co. for the years 1935-1938 gives an admirable analysis of the climate of that country and its neighboring areas [3].

Climatic studies on Afghanistan are more meager still and the work of Edward Stenz almost exhausts the list [4].

Turkey's climate has been systematically studied by Dr. Ludwig Weikmann who, in his book « Zum Klima der Tuerkei », gives a most detailed account of the climate of the Anatolian Plateau [5]. However, Weikmann's work does not include the results of the more recent investigations made by the present regime in Turkey [6].

In this connection reference may be made to a remarkable study by G. Bauer which can be considered a major contribution to the meteoro-

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[1] Banerji (G.), *The Meteorology of Persian Gulf and Makran*, Central Publications, Calcutta 1921.

[2] Normand (Charles William Blyth), *Climate and Weather of Iraq*. Baghdad Weather Bureau, Iraq Government Press, Baghdad 1919.

[3] Boesch (Hans H.), *Das Klima des Nahen Osten auf grund neueren Beobachtungsmateriales der Iraq Petroleum Company aus den Jahren* 1935-1938, Naturforschende Gesellschaft in Zuerich, Vierteljahrsschrift, 86 (1-2) : 8-66, 1941.

[4] Stenz (Edward), *The Climate of Afghanistan, its aridity, dryness and Divisions*. Polish Inst. of Arts and Sciences in America, New York 1940.

[5] Weikmann (L.), *Zum Klima der Tuerkei. Ergebnisse dreijaehriger Betrachtungen* 1915-1918.

[6] Publications of Turkish Meteorological Dept., mostly in Turkish language.

logy and climatology of Southwest Asia [1]. Bauer's study covers a vast portion of the Old World (from Mongolia to Bangalore and from Milan to Semipalatinsk). For the entire area Bauer has used 139 stations of which only nine are from Iran. Nevertheless, his work is of immense value to any climatic study of the Middle Eastern countries.

Not much is known of the work carried out by the Russians along the northern frontiers of Iran but the Great Soviet World Atlas of 1938 contains numerous climatic maps of the Caucasia and Turkistan. Unfortunately, all these maps represent areas included within the U.S.S.R. borders and cannot be utilized for Iranian territory [2].

Across the Persian Gulf on the Arabian main land, the extensive oil industry of recent years has greatly stimulated climatic studies, especially in view of the health of American technicians working in the oil fields and some of the results are already appearing in the handbooks and publications of the oil companies.

Present state of climatological investigation in Iran

Not unlike many other countries of the world, Iran is very unfortunate in having no long term climatic observations. There are about a dozen stations all over the country that can boast of records ranging from twenty to fifty years, but these are too far apart and their data too incoherent in terms of time, to form a sound basis for any systematic study. Among such stations may be named, in order of length of observational periods; Bushehr (sometimes spelt Bushire in English literature), Isfahan, Tehran, Kerman, Mashad (spelt Meshed in English books but actually Mash'had in its original form), Seistan, Jask, Tabriz, Kermanshah and Shiraz, for which detailed data are available in the archives of the Indian Meteorological Department in Simla, India [3].

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[1] Bauer (G), *Luftzirculation und Niederschlagsverhaeltnisse in Vorderasien*, Beitraege zur Geophysik, 45, 1935, pp. 381-385.

[2] Great Soviet World Atlas, Moscow 1938, Russian text, headings and keys translated and published in English by G. B. Cressy, Syracuse, 1940.

[3] Normand, *op. cit.*, p. 4.

In the early years of World War II, Iran was considered a vital area for the Allies and it was therefore occupied by them and was made the « Bridge of Victory » over which most of the essential war time requirements were sent to Russia. Roads had to be built under various climatic conditions and the traffic had to be maintained in all kinds of weather. Soon a close net-work of airways was established all over the country and it was not long before Tehran became the largest and the most strategic air base of the Middle East. Then came the war time food shortages and famines all over the Middle East and particularly in Iran that was going through successive years of drought and crop failure. Attempts were made to make the country as much self dependent as possible. Consequently, a great deal of attention was focussed on its agricultural potentialities whose assessment required a good knowledge of climatic conditions. A number of research projects were introduced and put into operation and so began a new movement in the field of climatic studies.

Until that time the Iranian Ministry of Agriculture was in charge of collecting data from a number of stations in some provincial centers. The stations of this ministry were increased in number, modernized in equipment and, to a certain extent, staffed with better trained observers. In addition the Department of Civil Aviation was reorganized and the existing airports classified according to their landing facilities and observational equipments.

In 1948 the Iranian government adopted a Seven Year Development Plan. The help of foreign advisors was sought and the technicians of the Overseas Consultants Inc. of New York made exhaustive studies and submitted their reports and recommendations in five huge volumes [1]. The importance of climatic observations to the agricultural economy of the country was pointed out with due emphasis. Concurrent with these developments, the American Technical Aid Program, generally referred to as Point IV, was extended to Iran. The International Civil Aviation Organization, of which Iran has been a long standing member, also offered technical help and in 1951 three experienced Norwegian meteorologists, headed by Dr. Anda, were placed at the disposal of the Iranian government.

[1] *Overseas Consultants Inc. of New York,* Report on the Seven Year Development Plan of the Iranian Government, 5 vols., New York 1949.

The financial help of the Point IV and the technical assistance of the I.C.A.O. opened a new era in the history of climatic studies and investigations in Iran. Classes were established to train observers and forecasters. Stations were equipped with modern self recording instruments. According to the latest information available, there are at present twenty stations equipped with electric cup anemometer, barograph, mercurial barometer, hygrograph, nephoscope, raingauge, thermograph, wind direction indicator, sunshine recorder, theodolite balloon equipment, and visibility meters. In addition, internationally important air bases such as Tehran and Abadan, are equipped with radiosonde and radar apparatus and plans are on the way for gradual extension of such equipment to other stations as trained personnel becomes available. By the end of 1953 some 150 observers and 10 forecasters were trained under the new plan.

Finally, an independent Meteorological and Climatological Organization, comparable to the Weather Bureaux of other countries, was established on december 31, 1953 with the object of undertaking systematic studies in the fields of meteorology and climatology and, with the ambitious plan of increasing the number of synoptic stations to fifty and the total number of well equipped, properly staffed and efficiently run stations, to three times this number. One can only hope that in the years to come it will be possible to undertake proper and systematic study of the climatology of this part of the world.

Basis of the present study

It is a known fact that for a proper investigation of the climate of any region, the longer and the more regular the observations are, the more reliable and satisfactory the results of the study will be. Climatologists differ in opinion regarding the actual length of the minimum period of observation required for any climatic generalization. Cycles of eleven

or thirty years have been considered sufficient by some writers (1). Others maintain that in regions that show great variability in such climatic elements as rainfall, longer periods of observation are necessary to give the accuracy that can be obtained in shorter times in regions of more regular precipitation. In Eastern Mediterranean, to which Iran may be said to be very similar in many climatic aspects, Erwin R. Biel thinks that approximately 80 years of records are required to give the same degree of accuracy attained in a thirty years period in areas with greater rainfall regularity (2).

It is definitely more desirable to have a long set of records at one's disposal before entering upon a regional climatic study but this is an ideal that cannot be attained in many parts of the world. Indeed there are only very few countries in the world that have a fine set of climatic data comparable to those of the U.S.A. and the United Kingdom. This does not mean that less fortunate areas, in this respect, should not be considered or that one should wait until such time when complete material becomes available, for every observation, or set of observations, can have its value as long as the existing limitations are understood. Besides, every study, however incomplete, is a step forward towards completion and unless the existing irregular data are coördinated and brought together in a systematic way no progress can be made in the scientific investigation even when more information become available.

The aim of the present study is threefold :

1 : To make an attempt to fill the gap that at present exists in the Middle East as far as Iran is concerned.

2 : To limit the study to a definite, but at the same time fairly sufficient, period of time.

3 : To utilize some hitherto unpublished and formerly non-available data.

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(1) Blair (Thomas A.), *Climatology, General and Regional,* New York 1942, p. 92.

(2) Biel (Erwin R.), *Climatology of Mediterranean Area;* Chicago University Institute of Meteorology, Miscellaneous Reports, No. 13, 1944, p. 10.

To achieve the above aim it was thought advisable to rely, primarily, on the fresh material available especially in Iran, although some reference to former works is inevitable especially in the case of areas not covered by the existing data (1).

The data on which the present study is based were obtained from the Iranian Ministry of Agriculture through the courtesy of Tehran University. They belong to a period when the reorganizations referred to above had just started. They relate to the period 1940-1953 as will be explained later.

The data available in the files of the above mentioned ministry included the following material :

1 : Monthly absolute maximum and minimum temperatures.

2 : Monthly average temperatures.

3 : Monthly average precipitation.

4 : Monthly relative humidity.

5 : Average annual precipitation for a number of stations.

However, statistics were not yet tabulated or organized and no less than 100,000 figures had to be worked out before the maps and the material presented in this study could be prepared.

There were altogether 134 stations shown in the original data but, unfortunately, their records were, in a number of cases, incomplete or of a short duration only. When the data were all worked out and tables for individual stations prepared, 87 stations out of the 134, were selected for detailed study and these were the stations with more regular and comparatively long term records.

It should be added that the data under study did not cover the entire period for all of the 87 stations, and the number of stations with ten years or more consecutive record was only thirty percent of the total.

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(1) All through the present study the date for the two Persian Gulf stations of Bushehr and Jask have been obtained from published sources, to be introduced in the future sections.

The following table shows the actual position of the records as far as the length of period of observation is concerned.

No. of stations with : 13 years record.........	14	total : 28
12	6	
11	5	
10	3	
9	3	
8	5	
7	8	
6	4	
5	6	
— 5	33	
Total......................	87	

All throughout the present study emphasis will be laid on the 28 stations with more than ten years consecutive record and those with shorter periods of observation will be used to fill the gaps whenever necessary.

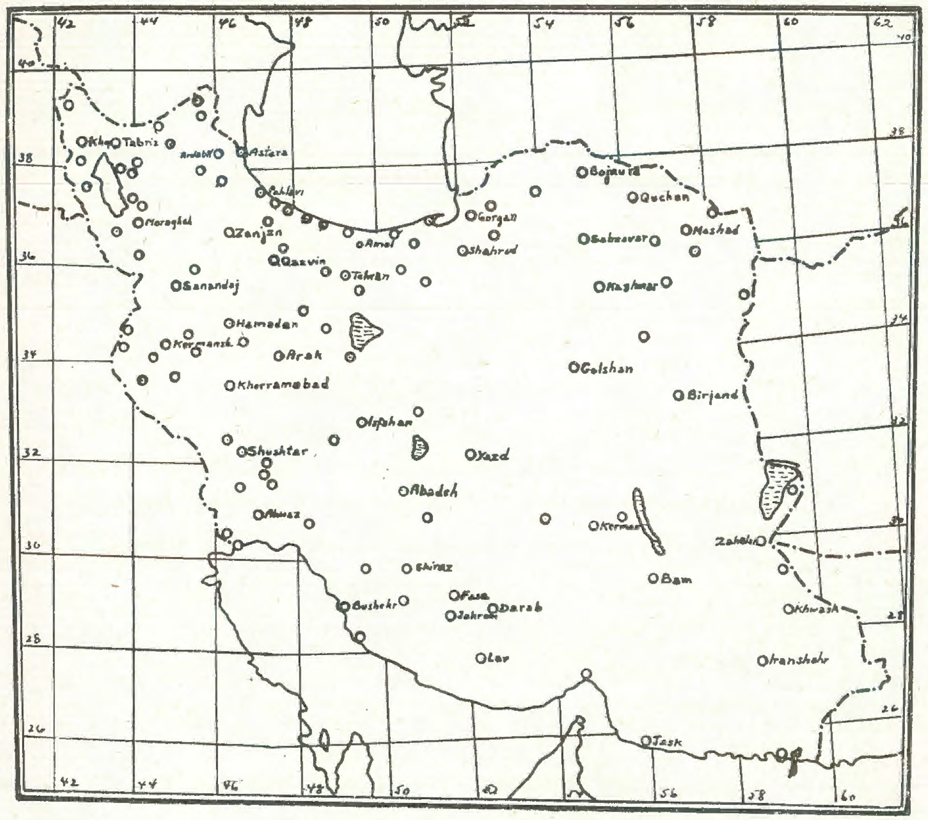
Not all the stations used in the present work had all the required data and the following table indicates the proportion of stations with various climatic data :

No. of stations with monthly max. and min. temperature and also rainfall records	42
No. of stations with mean monthly temperature and rainfall records	15
No. of stations with mean monthly temperature only	20
» » » » » » precipitation »	10
Total....	87

Distribution of climatic stations

Map No. 2 shows the geographical distribution of the existing climatic stations in Iran. Taking the total number of effective stations as 100 it will be seen that, at present, Iran has on the average one station to every 6,280 sq. miles of territory which is far from being sufficient to give an adequate and true picture of the geographical distribution of climatic elements. In the United States, with an area four times as

large as Iran, rainfall data are collected from 5,000 stations [1]. Great Britain with an area equal to one fifteenth of that of Iran and one rain measuring station to every 20 sq. miles, has 300 times more rain gauges per unit area than Iran [2]. There are in the sub-continent of India-



Map No. 2 : Distribution of Climatic Stations.

Pakistan altogether 3,017 meteorological stations (2,585 in India and 432 in Pakistan).

It is evident from the above figures that the present study based on less than 100 stations of not very long a duration, will produce only tentative results that must be completed as more data become available in the future.

(1) Blair (T. A.), *Weather Elements,* New York, 1937, pp. 354-358.
(2) Bilhelm (E. G.), *Climate of the British Isles,* London 1938, p. 75.

The great importance of topography in the climate of Iran will be repeatedly referred to in the future pages and therefore it is appropriate to survey the topographical or altitudinal distribution of the existing stations in this country. At present practically all the climatic stations are located either within or in the immediate vicinity of cities. This is mainly due to the economic factors but partly because of the difficulties involved in maintaining stations in remote areas.

An examination of the list of climatic stations shown in Appendix II will show that they are all below 2,000 metres in altitude. An analysis of the topographical distribution of the climatic stations used in this study brings this out very clearly as can be seen from the following table :

No. of stations situated between -26 and 500 m. (there are 14 coastal stations included in this figure)	26
No. of stations situated between 500 and 1,000 m	12
1,000 and 1,500 m	33
1,500 and 2,000 m	16
Total	87

As a result there is little information in Iran regarding the relation between precipitation and altitude. Another serious difficulty arising from the above situation is that the amount of snowfall which is such an important factor in the economic life of the country is not recorded at all. Until now no study has been made regarding the occurrence of this most important and valuable asset of the country and, evidently, no precipitation map would be fully reliable unless such records become available.

The flat lowlands of the interior of Iran show a striking lack of climatic stations. This is particularly true of the central deserts and their surrounding areas which have no great economic significance. Very little is therefore known about the climatology of the central deserts of Iran and the details shown on the climatic maps of these parts of the country should be considered quite tentative in nature.

Finally, a word should be added about the calendar system of Iran which had imposed another limitation upon the use of the statistics in

the present study. The Iranian year begins with the spring equinox; consequently divisions of the year are mainly seasonal and the months begin on or about the 20th of western (European and American) months. All the data available in Iran were naturally made for Iranian calendar months and in the absence of daily records, it was decided to push every month of the year back ten days so that it may correspond with an Iranian calendar month. For instance, all data used for January throughout this study refer to the period December 20th to January 20th. Similarly, the figures for July relate to the period June 20th to July 20th.

The Iranian seasons are clearcut and quite regular. Therefore the seasonal distribution maps presented here give a more exact picture than similar ones normally shown in climatic studies and books.

Chapter III

PRESSURE AND WINDS

Winter pressure conditions

During the cold winter months the interior of Asia is covered with a high pressure belt which results from the intensive cooling of the vast continent. Pressure is very high over Siberia (1,035 millibars), which also records the lowest temperature on earth, but it decreases outward in all directions. During this season most of the land surface of Eurasia is dominated by this high pressure and the Middle East falls naturally within this pattern. The winter high pressure belt, however, is not a continuous one. It is modified by topography and in the Middle East particularly, where high plateaux, lowlands and seas exist side by side, local conditions produce some complexity in the general pattern of pressure distribution.

The outlying portions of the high pressure belt extend westward over the northern Caspian regions into Europe and other tongues of high pressure exist on the Armenian and Anatolian plateaux [1]. The

[1] *Climate of Southwest Asia,* U. S. Weather Bureau Report No. 410, p. 14.

interior of the Iranian plateau too is most probably covered with a local center of high pressure during the winter months. There is, as yet, no definite information available regarding the intensity and behavior of this last mentioned center but its existence can be inferred from the examination of the rainfall maps of the country and also from the fact that the Mediterranean depressions that cross the country in winter, show a tendency to bypass the central deserts of Iran, and on such occasions their movement must be controlled by the existence of such a high pressure center over the interior of Iran.

In contrast with these centers of high pressure there are a number of lows that exert influence on the climate of Iran. To the north of this country the continuity in the high barometric pressure is broken by the existence of a relatively low center over the warm waters of the Caspian Sea whose northern sections are generally frozen under the direct influence of the Asiatic high [1]. Further west the Black Sea is covered with another center of relatively low pressure. During the winter months the Mediterranean Sea produces a pool of warm water surrounded by colder lands on all sides. Pressure over this large sea is therefore low and it is in the eastern section of this sea, namely in the neighborhood of Cyprus, that a semi-permanent low center of considerable importance exists [2]. Other centers of barometric minima within the wider high pressure belt of the continent of Asia can be observed over the Persian Gulf and the Sea of Oman.

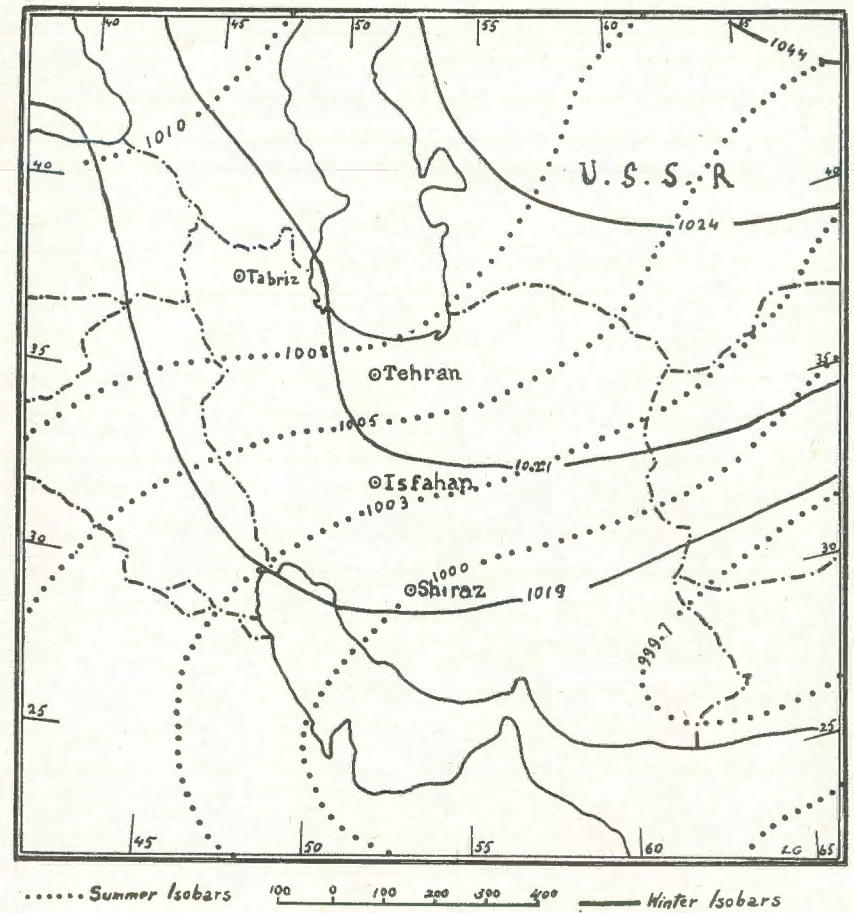
Within the above general pattern of the pressure system of the Middle East lies Iran over which pressure decreases from north to south as can be seen from map No. 3.

Summer pressure conditions

With the onset of spring in the northern hemisphere the high pressure belt of the heart of Asia begins to disappear and with it the pressure pattern over the entire continent shows a corresponding change. In Iran the interior of the country warms up fairly rapidly and low

[1] *Ibid.*, p. 15. [2] Biel (E.), *op. cit.*, p. 10.

pressure pushes its way northward from the southern and southeastern parts of the country. There is a brief transitional period during March and April. In May the summer pressure pattern is almost well established and the interior of Iran is dominated by a belt of low pressure



Map No. 3 : Pressure Conditions.

that extends from Afghanistan to Arabia. This low is, no doubt, an extension of the continental low pressure system whose center is found in the rainless deserts of Pakistan where in July the isobars show values as small as 997 millibars.

14.

During the summer months the monsoonal low pressure of India and Pakistan is definitely the most important climatic control in Iran. This low pressure system which is produced by the excessive heating of the southern parts of Asia, is a permanent feature of the summer months and the strong wind system to which it gives rise effects not only Iran but almost all the Middle East as well as the entire Indian sub-continent. This great belt of low pressure is prolonged over the Persian Gulf and over the southern provinces of Iran into Iraq and is eventually joined with another minor center developed over Cyprus [1].

Pressure is relatively high to the north of Iran and over this country the isobars run almost parallel from northeast to southwest with decreasing values towards the latter direction as shown in map No. 3. There is not a great deal of difference in the general trend of isobars in winter and summer over Iran but, whereas in winter the southern half of the country is crossed by the 1,019 millibar line, in summer pressure over the same areas does not exceed 1,000 millibars, a fact which clearly indicates the great influence of the Indian low pressure over the country in the summer months.

In September the transition towards the winter conditions starts and early in this month pressure rises sharply (4 millibars) in the outlying sections of the Asiatic low over western Iran. Higher pressures begin to establish themselves to the north and the gradual shift to the winter pattern is quite clear [2].

Winds

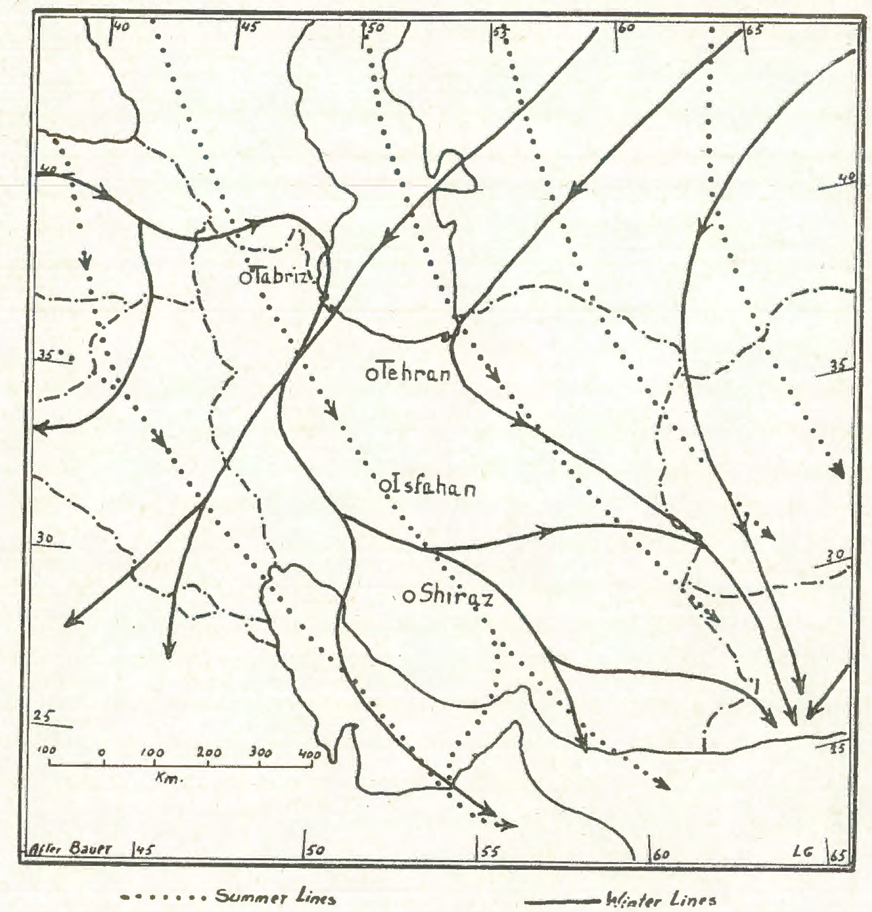
The study of pressure pattern over the country would, no doubt, lead to certain conclusions that may have theoretical value. In his admirable work on the climate of this part of the world, Bauer has included a number of monthly maps showing streamlines over the Iranian plateau and its neighbourhood. These are interesting and valuable in giving a general picture of the conditions of air movement but no definite opi-

(1) El Fandy (M. G.), *Barometric Lows of Cyprus; Quart. Jour. Roy. Met. Soc.* vol. 72, 1946, pp. 291-306.

(2) Biel (E.), *op. cit.*, p. 10.

nion can be expressed regarding the actual surface winds unless more data become available.

The Meteorological Report on West Persia is the only source that gives some detailed data regarding frequency of winds at a number of



Map no. 4 : Streamlines.

stations, such as Tehran, Qom, Isfahan and Abadan, but the data thus given are too meagre for any generalisation.

The accompanying map No. 4 showing streamlines has been adapted from Bauer's study already referred to in a previous section.

The general pressure pattern over Iran during the winter months

would suggest that throughout the cold months, winds must blow from the east or the northeast. This is, to a certain extent, the case because in the winter months a mighty northeasterly stream of CP air moves over parts of the Iranian plateau. The ultimate goal of this air flow is the low pressure vortex over north Africa [1]. However, it should not be thought that the easterly or northeasterly winds of central Asia are dominant at all times. Frequently, as will be seen shortly, masses of relatively warm and moist air from the Mediterranean break through over the Iranian plateau and not only improve the temperature conditions but, also bring rainfall and life to the country. The western half of Iran is more influenced by the western depressions and also by the masses of cold air that reach it from the north west and therefore the prevailing winds in this part of the country are northwesterlies during the cold season [2].

In the coastal areas of Iran, both in the Caspian and in the Persian Gulf, wind directions are determined by the local low pressure centers of the regions concerned. In the north i. e. along the southern shores of the Caspian Sea, an eddy motion, counterclockwise, is set up around the local low which is usually formed over the warm surface of the southern Caspian [3].

During the summer months the winds of Iran are dominated by the Indian monsoon system. However, unlike other monsoon areas, there is no reversal of wind directions from winter to summer in Iran because higher pressure prevails to the north at all seasons (northeast in winter and northwest in summer). The summer low of India and Pakistan influences the entire Middle Eastern area and in all sections winds generally blow towards this low center. In Iran wind direction over most of the plateau is more or less from the north or northwest but topography and the nature of the terrain play a great part in modifying this general picture and in determining the actual directions of the local winds.

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[1] *Climate of Southwest Asia, op. cit.*, p. 15.
[2] *Met. Rep. on West Persia, op. cit.*, p. 11.
[3] *Climate of Southwest Asia, op. cit.*, p. 15.

Local winds

In a country like Iran where extensive flat deserts, highly complex mountain systems, closed basins, long valleys, coastal plains, lakes and seas exist in close juxtaposition, topography is a major modifying factor and therefore the general picture outlined in the previous section seldom conforms with the actual surface winds which, almost in all cases, are caused by local topographical features.

Over the mountainous regions that constitute most of northern and western Iran, winds are quite variable and greatly influenced by topography. In the narrow mountain valleys they tend to be concentrated into two opposite directions and the up and down valley flows are a common feature of all such localities. During the day, as would be expected, winds blow up valley but, as soon as the sun sets and the air on the higher levels is chilled, a down valley flow of cold dense air sets in. The best example of this kind of wind can be observed in Tehran which owes most of its pleasant and cool summer nights to the air that flows down the valleys of the southern Alborz on to the city and its environs. In the hot summer evenings the mouths of the Alborz valleys attract crowds of peoples to such « promenades » of cool mountain air. In Shemiran, a summer resort to the north of the capital, thousands of inhabitants gather, on week ends and holidays, in a small space known as the Tajrish bridge, which is on the direct route of a down valley breeze.

The winds that flow off the high ranges of Alborz and Zagros produce a good deal of « foehn » effects over the Caspian Sea littoral zone as well as the interior of the country and the Mesopotamian lowlands [1].

Bora winds occasionally descend from the Alborz to bring cold waves over the flat deserts to the south. Similarly, downslope winds of the bora type sometimes blow off the Zagros ranges to the coastal areas of the Persian Gulf. Known by the local inhabitants as « Nashi », these cold bora winds carry considerable dust from the mainland far out over

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[1] *Climate of Southwest Asia, op. cit.*, p. 17.

the Gulf region. Such winds are the result of unusually high pressure over the interior of the country.

The Sirocco of the Mediterranean has no real counterpart in Iran. However, along the northern shores of the Persian Gulf and particularly in the rich oil districts of Khuzistan, in the cold months a southwesterly and warm wind, that has its origin in Arabia, blows occasionally with gale force, but unlike the Sirocco of the southern Mediterranean region, it brings a good deal of moisture due to its passage over the Gulf. This wind is locally known as «Saheli» and it is some times referred to as «Semoum», although the latter term is more strictly applied to the suffocating hot and moist air that overtakes these parts of the country during the hot summer months.

In the mountainous areas the effect of canalisation of the wind in the narrow mountain valleys and gorges cause unexpectedly strong winds in certain localities. The best example of such winds is to be seen in Menjil, where the Sefid-Rud valley provides a channel between the Caspian Sea and the interior wind systems. The wind that blows from north to south is such a permanent feature of the Menjil gap that the branches of olive trees grow horizontally parallel to the ground, and one can hardly find a single upright tree in the vicinity of the gap. Similar strong winds are common almost to all mountain passes that cross high ranges of the Alborz or Zagros systems.

Over the flat and barren lands of the interior of Iran, eddies and squalls are of common occurrance especially in the hot afternoons when the overheated air near the ground rises in funnel-shaped currents of dust. Currents of this nature are in fact miniature tornadoes that can be dangerous to all kinds of life but in the uninhabited deserts of Iran they develop and die unnoticed.

Over the coastal areas, land and sea breezes are common features but their effect, is primarily limited to narrow littoral zones because of the nature of the terrain. Along the southern shores of the Caspian where there is a combination of moisture and high temperature in summer, the night winds blowing offshore, mingle with downvalley currents of the Alborz ranges behind the coast and bring considerable relief to the inhabitants. In other sections where the coastal plain is extensive,

the land and sea breezes make themselves felt way in the interior. In the steppes of Moghan (the delta plain of Araxes-Kura), where a small portion of the flat land is included in the Iranian territory to the northeastern corner of Azarbaijan, the writer has noticed the tremendous effect of such breezes even as far inland as Shahabad, more than 100 km. from the sea. There the onshore winds that set in the early afternoon, when the land gets heated by the sun's rays, reach gale force and drive clouds of dust over the settlements.

Along the Persian Gulf coast such onshore winds are accompanied by great humidity which, when combined with excessive temperature produces considerable discomfort. The shores of the Persian Gulf have gained a bad reputation among the mariners and have been called «Hell's kitchen» and the like, by those who have suffered the unbearable conditions found there.

Of the all local winds that blow over Iran during the summer months, two have gained great popularity, namely the «Shamal» of the Persian Gulf coast and the «Wind of 120 Days» in Seistan. Both these winds are direct consequences of the low pressure center over India and Pakistan and both exhibit strong forces during the dominance of this low pressure.

The Shamal is a northwesterly wind that blows down the valley of the Tigris and Euphrates and also at the head and coastal areas of the Persian Gulf, from February to October, though with greater intensity and steadiness during the hot summer months [1]. The current is doubtless connected with the great monsoon development of India, since the period of its great intensity is concurrent with the monsoon period.

In southwestern Iran the Shamal is occasionally interrupted by the invasion of a deadly and suffocating mass of hot air from Arabia that absorbs considerable moisture during its passage over the Persian Gulf and produces a great deal of discomfort for the local inhabitants. This is the real «Semoum» or «Sam» wind as it is generally called. It blows

[1] *Climate of Southwest Asia, op. cit.*, p. 19.

predominantly in summer months and brings excessively high temperatures to the western foothills of Zagros in Iran as well as to the Persian Gulf coast as far east as Bandar Abbas. It invades Khuzistan and its effects are felt as far north as Shushtar and Dezful, where people seek refuge from the dust loaden wind, in deep cellars or underground dwellings sometimes 50 steps below the surface [1]. The wind is also referred to as «Shalji» and «Khormapazan», meaning «date cooker» because it ripens the date fruit.

One of the most striking climatic features of Iran that has greatly impressed all foreign travelers and writers is probably the «Bad-e-Sad-O-Bist Ruza» or «the wind of the 120 days», of the Irano-Afghan frontier region which attains its full development in the low basin of Seistan. The literature on this climatic phenomenon of Iran is definitely far more extensive than on any other climatic topic. Ever since the middle of the nineteenth century, travelers like Annandale, Goldsmith, Hedin, Huntington, Markham, Mohr, Sykes, Tate, Yate etc. have devoted long portions of their works to this wind which has received equal attention in the scientific works of Benerji, Bauer, Simson etc. [2]. More recently, G. Stratil Sauer of Vienna has published a paper, devoted wholly to this phenomenon, in which he discusses at length the nature, development, and domain of the wind in question [3].

The wind of 120 days blows from May to September from the northwest with great regularity, steadiness and sometimes violence. The wind normally begins towards the end of May. Actually the local inhabitants expect its commencement two months after the Iranian New Year or sixty days after the spring equinox. This is May 22nd and G. P. Tate, who more than any other one, has written on the characters of this wind, noted its punctuality in 1904 when it started with a strong gale that lasted four to five days [4]. Once begun, the wind blows incessantly throughout the summer months until September when it dies away gradually as the low center over Pakistan disappears from the maps of pressure distribution.

(1) Razm Ara (Ali), *Military Geography of Iran,* «Khuzistan», Tehran, 1943, p. 6.

(2) For full description of titles see bibliography.

(3) Stratil Sauer (G.), *Die Sommerstuerme Suedost-Irans,* Archiv fuer Meteorologie, Geophysik und Bioklimatologie, Serie B., Vienna, 1952, p. 133-153.

(4) Tate (G. P.), *Seistan, a memoir on the history and topography of the country,* vol. 1, London 1910, p. 164.

The direction of this wind seems to be fairly constant and Tate has again noted that its exact direction at its height, is 334 degree of the compass.

The speed of the wind varies from time to time and it can be said not to exceed 65 or 70 miles an hour. Nevertheless, its regularity and persistance make it a prominent feature in the physical conditions of the region as well as in the economic life of the inhabitants. When fully developed its destructive force is tremendous. It drives before it clouds of dust and gravel and is therefore an important agent of erosion. In his book on Seistan, G. P. Tate gives excellent accounts of the effects of this wind on the local landscape. He particularly indicates how, in the ruined cities of the past in this part of Iran, all walls at right angle to the direction of the wind had been completely removed by its violence [1].

Similarly G. Stratil Sauer, lays great emphasis on the effects of this wind in the physiography of the area where it dominates. As regards the origin of this wind, while admitting that to the rear of the well-known summer depression of Asia, there is a great predominance of north and northwest winds, Sauer maintains that summer storms developed from such currents within precisely limited regions are produced by large air masses precipitating into the overheated low grounds where the air has been thinner. Accordingly, the summer storms of eastern Iran are caused by morphological conditions [2].

(1) Tate (G. P.), *op. cit.,* p. 162.

(2) Stratil Sauer (G.), *op. cit.,* English summary, p. 134.

Chapter IV

TEMPERATURE

The primary climatic control in connection with the temperature in any part of the world is latitude, for latitude determines the amount of heat received directly from the sun in the form of radiant energy [1]. It is therefore necessary to remember the latitudinal position of Iran on the earth's surface. Iran is situated wholly within the temperate belt. The southernmost portion of Iranian territory on the Sea of Oman, namely the port of Gavator, is a little distance to the north of the tropic of cancer. Towards the north Iran extends almost to the 40 degree latitude.

Next to latitude, elevation above the sea is the most important control in the distribution of temperature. It has already been indicated that Iran is a plateau country of considerable elevation in which the total area of the land below 500 m. of altitude constitutes a smaller section of the total land surface of the country and can be said to be limited to very narrow coastal plains. Of the total surface area of Iran, estimated to be 1,640,000 sq. km. no less than 280,000 sq. km. or about one sixth has an elevation exceeding 2,000 m. [2].

Beside the actual elevation, land configuration is considered an important factor in determining the temperature distribution over the land surface. The air is heated and chilled chiefly by contact with the earth and its temperature changes will tend to be greater on flat land areas and less on convex surfaces such as mountains [3]. In Iran there are extensive stretches of flat deserts surrounded on all sides by tremendous mountains which encircle wide but closed basins. The rate of heating and cooling is therefore quite different in various parts of this country and the differential heating of the surface of the country is of great importance in the general temperature pattern of the country.

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(1) Blair (Thomas A.), *Climatology,* New York 1942, p. 46.

(2) Report on Seven Year Development Plan, *op. cit.,* vol. 3, p. 206.

(3) Kendrew (W. G.), *Climate, op. cit.,* p. 25.

Great water bodies are also considered important in controlling the temperature conditions of their surrounding areas. In the case of Iran, because of the peculiar layout of the mountains the influences of the seas are somewhat limited to their immediate neighbourhood and it is seldom that they play an important part in the control of temperature of the country beyond narrow coastal strips.

There is one more fact that deserves special attention in this brief survey of general temperature control in Iran. The country is exposed to the movement of air masses that have their origin in distant places and are therefore of totally different temperatures than those prevailing in Iran. Such air masses are likely to exert great influence on the pattern of temperature distribution in this country, especially during the winter season when the local control by insolation is weak. Imported temperature is therefore greatly responsible for producing the actual distribution of temperature particularly when the country is invaded by cold continental air of the heart of Asia.

January Temperature Conditions

Except in the narrow coastal region of the Caspian Sea, January is the coldest month of the year in Iran. The mean monthly temperatures vary between 19° C. in Jask to -3° C. in some of the higher stations in Azarbaijan. Of all the stations for which records are available only a few show a lower average in the following month. These are mostly in the Caspian littoral zone where the marine influences produce retardation in the monthly minima. The following table illustrates the temperature conditions in some of the Caspian stations :

Average January and February temperature (in Caspian stations)

STATION	J.	F.
Astara	5.0	3.7
Pahlavi	7.4	5.9
Rasht	8.7	4.0
Ramsar	8.5	7.9
Nowshahr	7.0	5.5
Gorgan	7.5	7.0

The warmest part of the country in January is the coast of the Sea of Oman where Jask records the highest for the entire kingdom, namely 19° C. Along the coast of the Persian Gulf moderate temperatures prevail and no station has a January mean that may fall below 10° C. Bushehr, Abadan and Ahwaz have a January mean of 14°, 11° and 14.8° C. respectively. The line of 10 degree isotherm follows the southern escarpment of the plateau almost parallel with the coastline but in the west swings northward to leave the entire plain of Khuzistan to its south (map No. 5).

January is the month when most of the absolute minima are recorded at many stations. The following table would illustrate conditions prevailing at some representative stations :

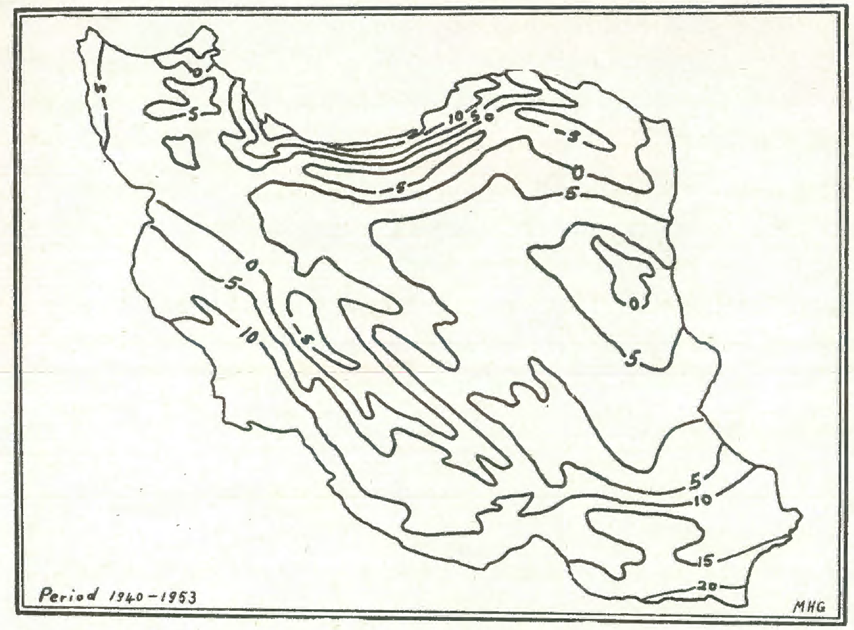
January temperature conditions at selected stations

STATION	Elevation	Av. max.	Av. min.	highest record	lowest record	mean monthly	observ. years
	m.						
Ahwaz......	66	21	0	25	— 2	14.8	11
Arak	1,880	10	— 18	12	— 24	0.1	13
Ardabil	1,570	12	— 18	17	— 30	— 1.9	10
Fariman	1,380	15	— 15	21	— 23	0.1	12
Isfahan	1,550	20	— 6		— 14	3.8	13
Ramsar	— 26	18	1	25	— 6	8.5	13
Shiraz	1,500	17	— 5	21	— 10	5.4	13
Tehran	1,200	13	— 6	17	— 11	3.3	13
Zabol	516	22	— 4	26	— 11	7.3	13

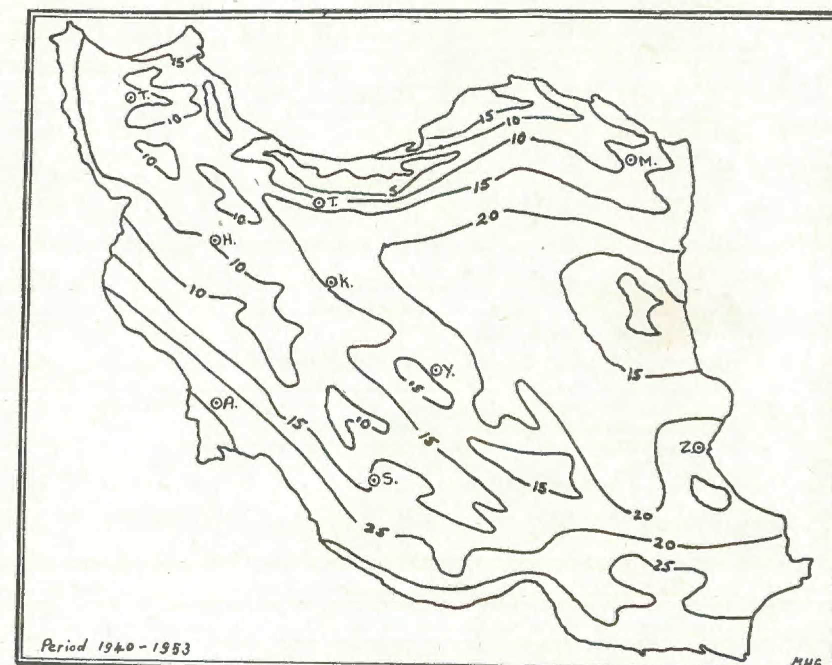
April Temperature Conditions

Except along the southern shores of the Caspian Sea, where the annual minima are reached in February, the passing of January marks the beginning of warming up of the land, a process that goes on until July and August. All isotherms therefore show a tendency towards a gradual upslope and northward movement. This can be easily seen from map No. 6 which shows the April temperature conditions.

In the south the 25° C isotherm makes its first appearance on the map. Jask and Abadan record both averages of above 25° C. but the means for Ahwaz and Bushehr still remain between 20° and 25° C.



Map No. 5 : January Temperature.



Map No. 6 : April Temperature.

The effect of rapid heating is more significant in the interior where the 20° C. dominates the realm. A similar change to warmer conditions is observed along the Caspian shores where most of stations show an average of about 15° C.

Over the highlands of the Alborz and the Zagros, the upslope and northwards movement of the isotherms, a process which goes on from March to July or August, continues with more rapidity with the result that the 0° C. isotherm disappears from most of the mountainous sections and is to be found only over the higher Alborz.

The following table brings out a general picture of the thermal conditions during April :

Average April temperatures at selected stations

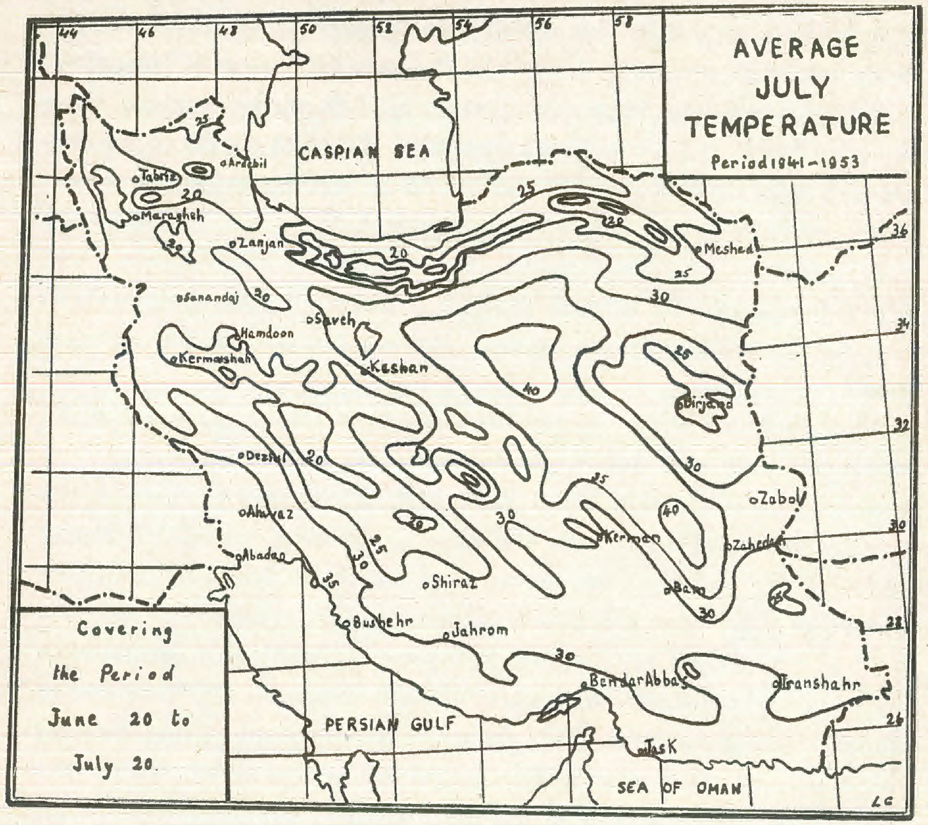
STATION	Temperature (centigrade)
Jask	26°
Bushehr	23
Abadan	25.8
Ahwaz	21.1
Shiraz	19.0
Kerman	16.5
Yazd	16.0
Isfahan	12.7
Arak	10.7
Sanandaj	10.0
Rezaiyeh	7.9
Tehran	14.8
Mashad	11.7
Pahlavi	13.1
Ramsar	12.4

July Temperature Conditions

The most critical months of the year from the point of view of temperature studies, are the mid-summer and mid-winter months during which extremes of temperatures usually occur. In an earlier section of the present study it was stated, with reasonable degree of certainty, that January was the coldest month in Iran. Unfortunately, no such conclusive statement can be made about July or August being the warmest month of the year in this country, partly because high values occur in both months and partly because of the calendar system of Iran, limitations of which have been already referred to in earlier sections. One thing, however, can be said with certainty. The fifth month of the Iranian calendar system, namely the month of «Mordad» which corresponds with the period July 20th to August 20th, is the hottest month of the year. The data for this Iranian calendar month have been used throughout the present study to correspond with the month of August, whereas they actually include the last ten days of the previous month.

A careful study of the temperature records of Iranian stations for the months of July and August would bring out certain interesting facts regarding distribution of temperature in Iran. It appears that the low and flat deserts of the interior and their surrounding regions get heated earlier in the year than the coastal areas where the retarding influences of the sea play a decisive part in the temperature conditions. Out of a total of 76 stations with temperature records, 34 show a maximum in July and in 42 stations the highest monthly temperature is recorded in August. The distribution of the groups of stations is interesting, because the first, i. e. those with a July maximum, are scattered all over the eastern and southern parts of the country where the altitude above sea level is lower than the rest of the country. In a general way it can be stated that stations below the 1,500 m. contour, with the exception of coastal stations, record their highest monthly mean in July. In the higher grounds of the Alborz and Zagros, as well as on the shores of the Caspian Sea, a majority of stations record their mean monthly maximum temperature in August.

The southern shores of the Caspian Sea are cooler in July than in August. Here the retarding influence of the sea is responsible for the situation. During July the middle sections of the Caspian shores enjoy lower temperatures whereas in August the 25° C. isotherm extends to the northern foothills of the Alborz; thus leaving the entire coastal areas within the same thermal averages as Tehran to the south. However in the capital, the dryness of the air makes conditions much more pleasant than in the humid coasts (map No. 7).



Map No. 7 : July Temperature.

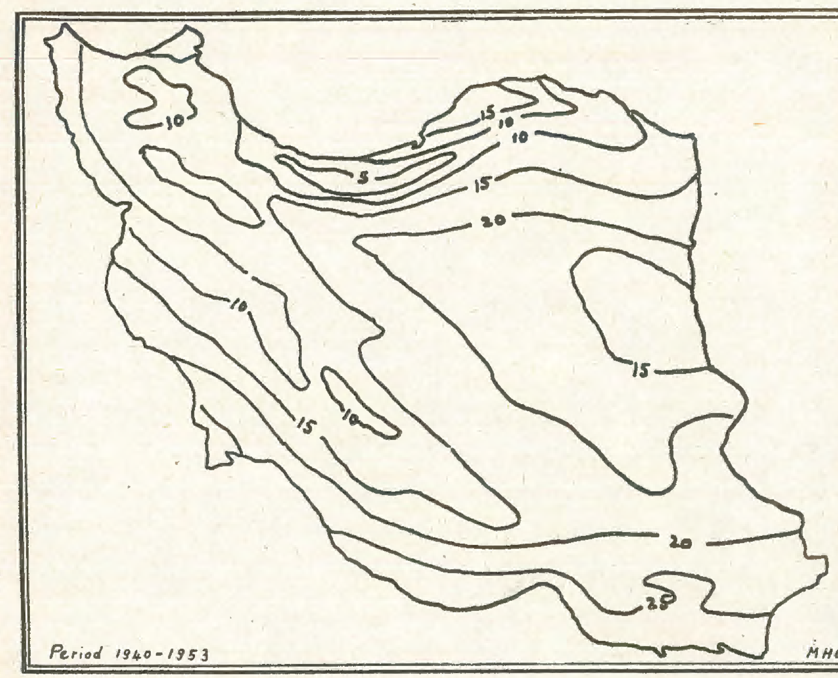
The following table would serve to illustrate the general July thermal conditions at selected stations :

STATION	Elevation	Av. max.	Av. min.	highest record	lowest record	monthly mean	observ. years
	m.						
Abadan	66	47	25	49	22	35.8	9
Ahwaz.......	66	50	21	53	20	36.2	11
Shiraz	1,500	42	12	43	9	26.1	13
Isfahan.	1,550	39	16	40	15	26.6	13
Arak.	1,880	35	15	43	4	26.6	13
Tehran......	1,200	41	18	44	15	30.6	13
Ramsar.	— 26	35	14	36	12	25.0	13
Rezaiyeh	1,300	34	12	39	10	23.2	11
Mashad......	940	42	9	43	5	27.7	12
Zabol.......	516	47	20	50	14	29.5	13

October Temperature Conditions

October is the typical autumn month of the year when more moderate temperatures make the climate of most parts of Iran quite desirable. During October, Tehran, like many other cities, has a pleasant climate that attracts crowds of visitors and tourists.

Temperature conditions are in general similar to those of April except



Map No. 8 : October Temperature.

in the southwest and along the Persian Gulf where maritime influences produce a lag in the lowering of temperatures. Khuzistan and the lowlands at the head of the Persian Gulf are the warmest parts of the country. Averages of about 30° C. are recorded in these parts of Iran even in October. The effect of quick cooling of the interior of Iran is seen in the trend of 20° C. isotherm which dominates over an extensive area.

The following table, as well as map No. 8, bring out the general thermal conditions that prevail during October.

Average October temperatures at selected stations

STATION	Temperature (centigrade)
Jask	28.0
Bushehr	26.0
Abadan	27.2
Ahwaz	30.2
Shiraz	18.2
Kerman	20.0
Isfahan	18.6
Arak	17.9
Sanandaj	18.7
Rezaiyeh	14.3
Tehran	21.0
Mashad	16.1
Pahlavi	19.0
Ramsar	21.4

Temperature types or Thermal provinces of Iran

(*See p. 299, graphic.*)

In his admirable study of the climates of the United States, F. D. Ward has introduced a system of composite temperature curves or temperature types in order to illustrate the general characteristics of thermal conditions over wider areas rather than in individual stations which tend to portray the conditions prevailing in their immediate neighbourhoods [1].

An attempt is here made to apply the same method to the temperature conditions in Iran, although it is quite clear that in view of the small size of this country as compared with the continental United States, the results of this analysis may not be as impressive as those included in Ward's study.

A careful study of the temperature data in Iranian stations enabled the writer to recognize five distinct groups for which composite curves were worked out and are here shown on a chart No. 9. The groups in question may each be called a «temperature type» and the area dominated by each group may be referred to as a temperature province because of the similarities displayed by the individual stations included within each group. The five temperature types thus recognized are :

I : Capsian type ; represented by Astara, Pahlavi, Babol and Gorgan.

II : Persian Gulf type ; represented by Jask, Bushehr and Abadan.

III : Western Highland or Zagros type ; represented by Rezaiyeh, Sanandaj, Borujerd and Shiraz.

IV : Northern Highland or Alborz type ; represented by Tehran, Sabzevar, Mashad and Quchan.

V : Interior Lowland type ; represented by Yazd, Kerman, Zahedan and Kashmar.

The Caspian type is characterized by low annual range and relatively higher values in winter and lower ones in summer. This is the only type in which the minimum monthly mean is reached in February. August is the month with the highest mean temperature in the year and both these characteristics are due to the retarding influences of the sea as already discussed at some length.

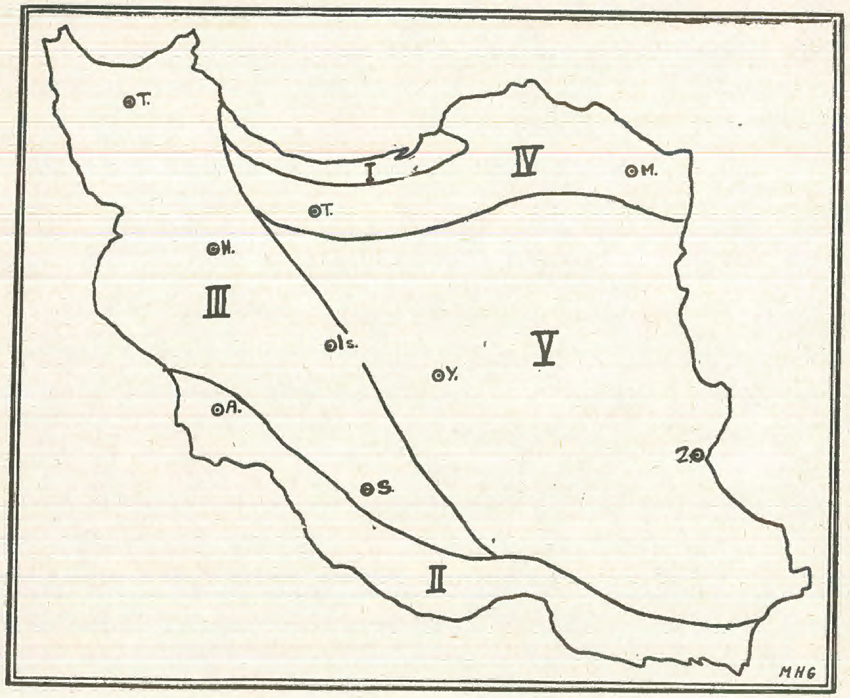
In chart No. 9 the curve illustrating the conditions of the Persian Gulf type of temperature stands out for its high values and relatively small range when compared with other types. January is the coldest month but it is interesting to note from the chart that the mean for this month is higher than that of April in all other types. July is the hottest month but here again the mean for this month is 4 to 10 degrees above those of other types.

The Zagros type of temperature is characterized by a very low January mean value which almost approaches the freezing point. August is the warmest month here but the average for the month is below those of any other type shown on the chart. The higher annual range in this type when compared with the above mentioned maritime types is quite striking.

The Alborz type is not very different from that of Zagros in general trends but it records, on the whole, higher temperatures with a relatively greater annual range. July is the warmest month of the year in this type.

[1] Ward (Robert De Courcy), *The Climates of the United States,* Boston 1925, p. 93.

The curve for the interior type is striking because of its great annual range, which is the greatest of all types, and also for its high values. The average monthly temperatures in this type, although higher than many of the types outlined above, fall below those recorded along the Persian Gulf.



Map No. 9 : Temperature Provinces of Iran.

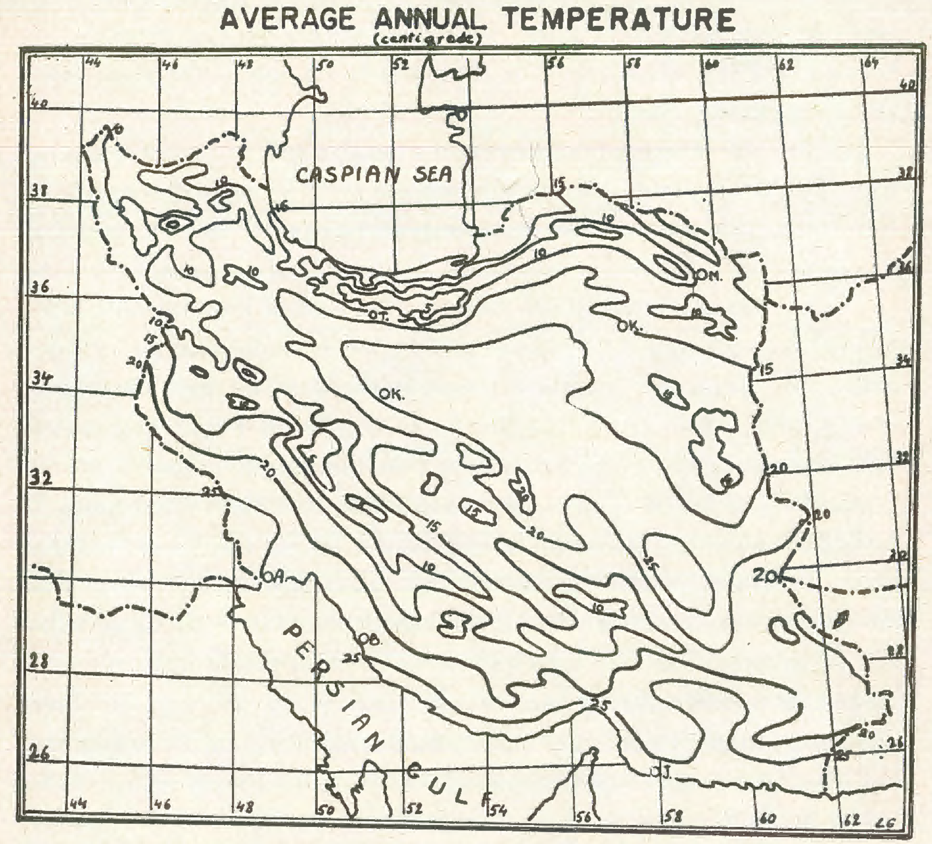
Map No. 9 has been prepared to illustrate the approximate boundaries within which each of the above mentioned temperature types predominate.

Mean Annual Temperature

Map No. 10 illustrates the average annual temperature of the country for the period 1940 to 1953 for which data for 76 stations were available. The map has been constructed with due regard to the lapse rate of 5 degrees centigrade to every 1000 m. of altitude, but the lapse

rate has been utilized mainly for the regions of below 1000 or above 2000 m. in altitude. Between these altitudinal belts isotherms have been mainly drawn with the help of data plotted on the map.

The great influence of latitude and elevation as major controls in the distribution of temperature, can be clearly seen from this map in which



Map No. 10 : Mean annual Temperature.

isotherms decrease in value from south to north and from lower to higher elevations.

The maritime influence of the Caspian Sea in the north and the Persian Gulf and the Sea of Oman in the south is indicated by the parallelism that exists between the coastlines and the isotherms in both areas.

The main ranges of Alborz and Zagros mountains stand out quite distinctly in the map in which all land with an altitude of more than 3000 m. appear as islands of cold temperature.

The warmest part of the country on the average annual temperature map is the narrow coastal plain adjoining the Sea of Oman.

In the southeast of the country the lowlying Jaz-Murian basin presents another warm area where very high temperatures are recorded in summer and the whole region is supposed to be one of the most desolate in the entire country [1].

The interior deserts of Iran form an extensive belt of higher temperature all the way from the neighbourhood of Tehran, in the north, to Kerman in the south. The desert extends eastward into Afghanistan where similar temperature conditions most probably prevail.

To the west and north of the desert belt of central Iran annual temperatures decrease under the influence of higher latitudes and also greater altitudes. Generally speaking, temperatures decrease over Iran from southeast to northwest. Thus the Zagros highlands form a continuous belt of lower temperatures all the way from the neighbourhood of Shiraz to Azarbaijan, but it is in the latter province that the coldest parts of Iran are centered. Azarbaijan is well known for its very severe winters when the entire plateau is invaded by cold waves from Russia. The lowest annual temperature for all the existing stations come from Ardabil, at an elevation of 1,570 m., to the east of Azarbaijan and only 60 km. from the western shores of the Caspian Sea by a straight line. The mean annual temperature at this station is 9.4° C. only. During the ten years for which records are available this station has also recorded the lowest absolute minimum of -30° C. Sub-zero (centigrade) temperatures are recorded at Ardabil eight months every year and the mean monthly minimum temperature falls below 0° C. in seven months of the year.

The highest temperature recorded in Azarbaijan during the period used in the present study is 39° C. This is particularly significant in view of the fact that most stations outside this area record maxima of above 40° C.

[1] Razm Ara (Ali), *Military Geography of Iran, Mokran, Tehran.* 1941, p. 83.

The severe conditions prevailing in this province can be seen from the following table that supplies the number of months with sub-zero temperatures.

STATION	Elevation	Number of months with mean minimum below 0° C.	No. of months with average below 0° C.	Years of observation
Ardabil	1,570 m.	8	2	10
Ahar	1,459 m.	6	3	7
Azarshahr	1,096 m.	no data	3	4
Ajabshir	1,400 m.	6	1	7
Khoy	1,370 m.	6	2	9
Maragheh	1,618 m.	6	2	9
Marand	1,462 m.	no data	2	12
Rezaiyeh	1,300 m.	6	2	11
Tabriz	1,360 m.	no data	2	12

The warming effects of the Caspian Sea on its southern shores are distinctly brought out in the annual temperature map, which has a greater degree of accuracy in this section, thanks to the greater number of stations in the area. Temperatures are fairly uniform in this coastal belt; averages ranging from 15 to 17° C. Sub-zero temperatures are occasionally recorded and the highest record available is 40° C. for Gorgan.

No information is available regarding the temperature conditions over the Alborz proper and the stations such as Karaj and Tehran, on the southern foothills, represent more the interior conditions than the mountainous areas. In the east, however, it is certain that the outlying branches of the Alborz experience colder temperatures, especially in the northeastern corners of the country which are in the direct path of the Asiatic cold waves. In Mashad mercury sinks to below freezing six months of the year and absolute minimum of -25° C. has been recorded at this station. It should be noted that unlike Azarbaijan, in the mountainous sections of Khorassan, here very high temperatures can be observed in the summer months. This is because the region is a link between the hot deserts of the interior of Iran and the overheated wastes of southern Turkistan. Mashad has recorded an absolute maximum of 43° C. which has nothing analogous in Azarbaijan.

Annual Range of Temperature

The annual range of temperature is defined as the difference between the mean temperatures of the warmest month and of the coldest month [1]. The annual range of temperature increases with the increase in latitude because of the greater difference between winter and summer insolation as the distance from the equator becomes greater. The distance from large bodies of water is another factor that influences the annual range in temperature of any place on the earth's surface [2].

As far as Iran is concerned, the effects of both the above mentioned factors are clearly observed in the study of monthly mean temperatures which vary considerably from season to season and place to place.

The lowest annual range is found in Jask which is situated on the sea and also has a very southernly position. Here the difference between the coldest (January) and the warmest (July) months is 14° C. only. Bushehr, a port of the Persian Gulf, 3 degrees further north than Jask, shows a mean annual range of 18 and the two stations portray very well the conditions prevailing along the southern seas of Iran except in the low plain of Khuzistan. Here the annual range in temperature suddenly assumes a continental aspect and Ahwaz has an annual range of 25 degrees.

The Caspian littoral belt is another part of the country with great maritime influences and consequently low annual ranges. Along this coast the annual range in temperature varies from 18 to 22° C.

Outside the above mentioned maritime provinces, the annual range of temperature is considerable everywhere on the plateau. Generally speaking, the range varies from 25 to 30 degrees with the stations in Azarbaijan and the high Zagros, as well as those surrounding the deserts, showing a tendency to greater annual ranges. The highest annual range for the whole kingdom comes from Mianeh, at an elevation of 1,220 m. This is the first city of Azarbaijan when one approaches this province

(1) Blair (Thomas A.), *Climatology, op. cit.*, p. 17; Miller (Austin), *Climatology, op. cit.*, p. 10.

(2) Blair (Thomas A.), *Weather Elements, op. cit.*, p. 285.

from the capital. Over a period of nine years this station has recorded the following monthly means of temperature :

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
-2.8	-1.0	2.8	8.4	14.3	22.0	26.1	27.7	22.9	16.6	7.7	2.9

thus giving an annual range of 30.5° C. which is the highest on record in the country.

Continentality

An interesting aspect of the climate of Iran is its continentality. The term applies to the climatic conditions resulting from the distance from the sea and the effect of differential heating and cooling of large land masses and water bodies. Where there are no mountain ranges, marine influences decrease gradually inland to the center of a continent and considerably beyond this center if influenced by the direction of the prevailing winds [1]. In such cases, the direct distance from the sea can be an important factor in determining climatic types. However, where there are influences of the mountains, as in Iran, distance from sea is not a good measure of continentality, which is better expressed in the annual range of temperature than in any other climatic phenomenon.

The most obvious characteristics of continental climates are high diurnal and annual ranges of temperature, already discussed at some length in the case of Iran.

Many methods have been proposed for determining the degree of continentality or oceanity of climatic stations and many formulas have been devised for obtaining this degree in terms of figures. In his «Methods in Climatology», Victor Conrad of Harvard University, emphasizes the great importance of the annual range as a measure of continentality but, he adds that «because a general physical correlation exists between the annual range and the geographical latitude, the range has to be reduced to equality for all latitudes» [2]. Conrad gives the expression

(1) Blair (T. A.), *Climatology, op. cit.*, p. 54.

(2) Conrad (V.), *Methods in Climatology*, Cambridge, Mass., 1946, p. 195.

A : sin Φ as a factor for this reduction and proposes the following formula for obtaining continentality :

$$C = \frac{1.7 \times A}{\sin \Phi} - 20.4$$

where C is the coefficient of continentality in percent, A the annual range of temperature in centigrade and Φ the geographical latitude.

In his study of Climate of Afghanistan, Ed. Stenz has utilized a similar formula, introduced by W. Gorczynski, and has concluded that continentality is the most characteristic trait of the climate of Afghanistan [1]. Stenz's conclusion applies equally to a great section of Iran, especially in the eastern half of this country which has many climatic aspects in common with Afghanistan.

In his « Climatology of the Mediterranean Area», Erwin R. Biel has utilized F. Kerner's « thermoisodromic quotient» for determining the continentality of various stations. He argues that in a maritime climate autumn is warmer than spring because of the slow cooling and warming of the sea. The difference October temperature minus April temperature (both months being at approximately the same interval of time from the summer solstice) is bound to be the greater, the more definite the influence of the sea is, and, smaller the more definite the continental features are. The thermoisodromic quotient Q (the term meaning a quotient in negative of the course of the thermal curve) is expressed by

$$Q = \frac{100\,d}{R}$$

where d is the difference between October and April average temperatures and R the annual range. Continental stations with small values of d and high values of R experience small quotients, while the opposite is true for marine stations with great values of d and small ones of R [2].

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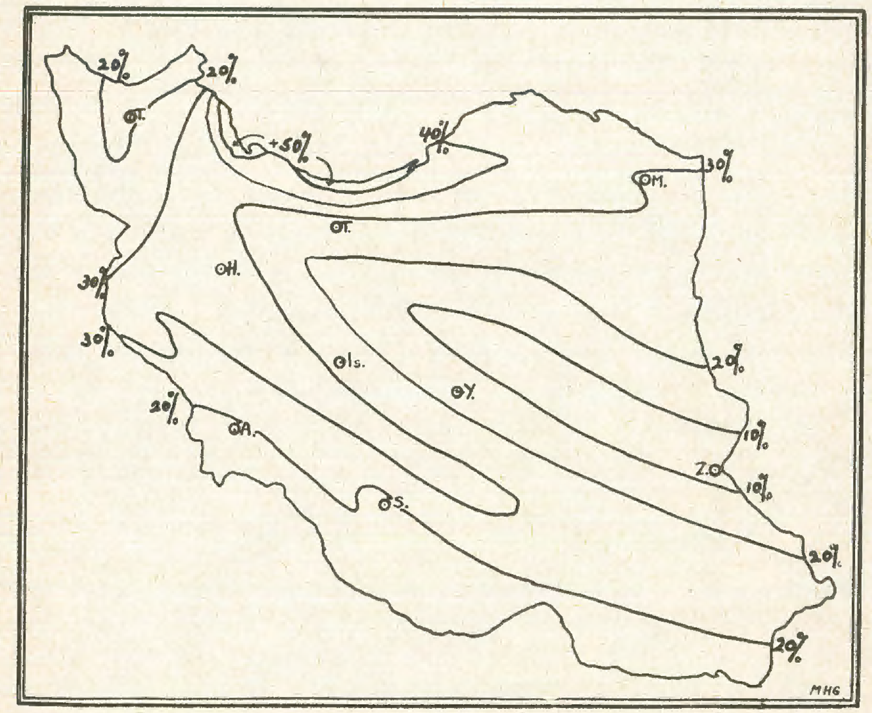
[1] Stenzd (Ed.), *op. cit.*, p. 10.

[2] Biel (Erwin R.), *Climatology of the Mediterranean Area*, Chicago University Institute of Meteorology Miscellaneaous Reports, N°. 13, 1944, p. 147-148.

In the present study the last named formula, namely that of Kerner was used because of its great simplicity. Thermoisodromic quotients were worked out for all stations with temperature data. The results have been plotted on map No. 11 which shows the continentality in Iran.

The degree of continentality in all the proposed formulas varies be-



Map No. 11 : Continentality.

tween 100 for the totally maritime stations and 0, for the most continental ones. The computation of index of continentality for 76 stations with temperature data revealed that the extreme values, as far as Iran is considered, vary between 6 for the oasis station of Golshan (formerly known as Tabas) and 60 for Astara on the Caspian Sea. Golshan is a typical desert town to the east of the central desert of Iran, better known as « Kavir», at an elevation of 722 m. It is the northernmost limit of

palm growth in Iran and is also well known for its citrus fruit [1]. Golshan has an annual range of 28.5° C. but April and October means of 20.1 and 21.9 respectively which results in a difference of 1.8 only. The thermoisodromic quotient for this station is therefore $\frac{1.8 \times 100}{28.5} = 6$

Other stations with low quotients, i. e. with high degree of continentality are those scattered around the central deserts as can be seen from the following table;

Zahedan	8
Shahdad	11
Zabol	13
Khash	14
Kerman	14

The degree of continentality decreases as one approaches the higher grounds and eventually reaches the coastal areas. Generally speaking, it varies between 20 and 40 in most of the inhabited sections of the plateau but around the Caspian Sea, where prominent maritime conditions prevail, the index is quite different as can be seen from the following table;

Astara	60
Babol	60
Ramsar	55
Shahsavar	54
Nowshahr	56

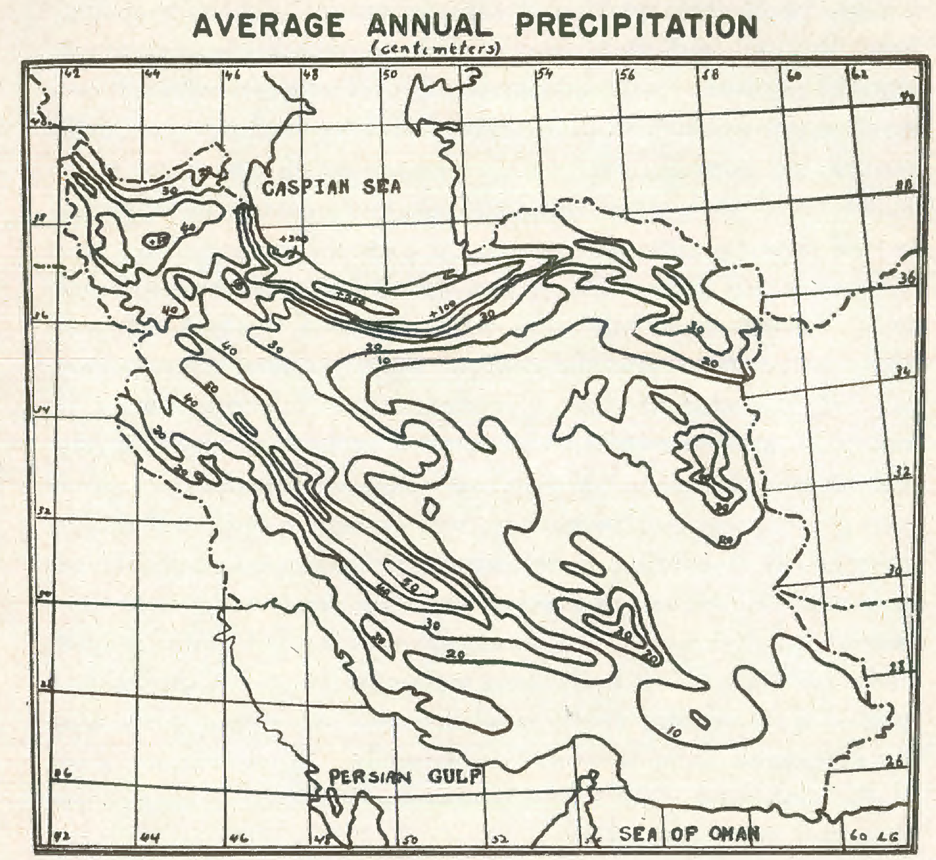
Chapter V

PRECIPITATION

Average Annual Precipitation

The map of average annual precipitation in Iran (map No. 12), presented and discussed in this study is based, primarily, on the data for 94 stations (for the period 1940 to 1953), supplied by the Iranian Ministry of Agriculture.

[1] Detailed accounts of the geography of this oasis are contained in the travel books of the eminent Swedish geographer Sven Hedin, particularly in his two volume work entitled *Overland to India,* London 1912.



Map No. 12 : Average annual Precipitation.

In addition, to fill in some wider gaps that existed in the map due to uneven distribution of climatic stations, average annual figures for some places, especially in the southern sections of the country, were taken from various works of Dr. Hans Bobek, who more than any other contemporary geographer, has written on the climate of Iran, particularly on the period that coincides with the period of the present study [1].

[1] Dr. Hans Bobek, formerly of Berlin University and now professor of geography at Vienna University, has for years engaged himself in the study of various geographical problems of Iran. In post war years, he has switched over from morphology, once his main field of interest, to ecology and plant geography in which lines he has published some excellent papers (see bibliography).

The altitudinal distribution of Climatic stations in Iran has already been discussed and the deplorable lack of stations above 2,000 m. altitude has been duly emphasized. The difficulty encountered as a result of this unfortunate distribution of stations was far greater in the construction of rainfall maps than in the making of temperature maps. In the latter case a certain lapse rate was used, whereas in the case of rainfall maps no such criterion was available.

Climatologists generally agree that, precipitation increases with altitude, although at various rates, up to the level of about 2,000 m. after which it shows signs of decline [1]. The complete absence of mountain stations and, similarly, the absolute lack of information as to the amount of rain or snowfall that is deposited on the higher levels in Iran, make it very difficult to arrive at any conclusion regarding the rate of increase or decrease of precipitation with altitude in this country. The geographical distribution of the existing stations makes the conditions even more difficult for, in a majority of cases, large distances, intervening valleys and basins, and mountains produce unfavorable grounds for comparison. A close study of the position of the cities in the highland section of the country would reveal that they are generally located in the rainshadow of the moisture bearing winds. To mention only a few in the western highland section, Rezaiyeh, Mahabad, Sanandaj, Bijar, Hamadan, Kermanshah, Malayer, Borujerd, all lie to the east or north-east of mountain ranges or on the leeward side as far as the moisture bearing westerlies of the winter season are concerned. All records made at such stations can therefore be considered below the actual amount of rain that falls on the higher elevations or on the windward slopes of the surrounding hills. It is as a result of this peculiar situation that great anomalies can be expected due to topographic influences. Qasr-e-Shirin, on the Iraqi border region, at an elevation of 645 m. has an annual rainfall of 354 mm., whereas Kermanshah, almost on the same latitude, at an elevation of 1,472 m. records 332 mm. only. The

[1] HANN (J.), *Handbook of Climatology, op. cit.*, p. 295-309 BLAIR; (Thomas A.), *Climatology, op. cit.*, p. 80; TREWARTHA (Glen A.), *op. cit.*, p. 350 and MILLER (Austin), *op. cit.*, p. 40.

westerly winds of the winter months that effect both these stations have to cross about 130 km. in a straight line and negotiate, at least, three mountain ranges of considerable height before they reach Kermanshah. It is therefore quite clear that the potential rain producing capacity of such winds undergoes great changes from one station to another and, as long as stations at varying elevations on the same slope, do not come into operation, it will be practically impossible to arrive at any conclusion regarding the relation between altitude and precipitation in Iran.

Of the twelve stations in the Caspian area, used in the present study, six, namely Astara, Pahlavi, Ramsar, Nowshahr, Shahsavar and Ashuradeh, are actually on the coast and four—Lahijan, Rasht, Babol and Shahi—only a few kilometers back from the coast, at elevations not exceeding 20 m. Gorgan is the only station that lies some 60 km. from the coast in a straight line. Near the coast is the island of Ashuradeh, at an elevation of 26 m. below sea level with an average annual rainfall of 467 mm. Gorgan, some 60 km. to the east of this island has an elevation of 116 m. and an annual rainfall of 1,154 mm. which gives a rate of increase, in precipitation, of 48 mm. per 10 m. of altitude.

Whatever the rate of increase or decrease of rainfall with altitude may be, it is certain that the higher sections of mountains, especially along the northern slopes of the Alborz, receive a considerable amount of precipitation annually. This is more apparent when one observes the heavy snowfalls which at times accumulate to more than 3 m. in passes no more than 2,500 m. high. The persistance of snow in the Alborz is so that Demavand is permanently clad in snow. Even on the southern slopes of Towchal which lie immediately to the north of Tehran, snow covers most of the higher grounds from October to April and patches of snow can be seen from the capital as late as June. The same statement can be made about the Zagros and similar hilly sections of the country.

The accompanying five precipitation maps have been prepared on the assumption that precipitation is higher on the upper reaches of the mountains than that indicated by the existing data. Below the 2,000 m. contour, isohyets have been drawn on the basis of the data plotted on

the maps with due consideration of the land configuration. Above this line, they have been constructed in conformity with the contours and with due regard to all the evidences that would indicate heavier precipitations on higher grounds.

Over Iran as a whole, precipitation decreases from north to south and from west to east progressively except where relief of the land upsets the regularity in this arrangement. This is particularly the case in the area between Abadeh and Shiraz, in the north-south traverse of the country and, to a certain extent, over the highland of Qayenat to the east and before the Afghan frontier is reached.

The mean annual precipitation for the entire country amounts to 416 mm. This value by itself is rather misleading because only a small proportion of the land surface of Iran, namely that part of the Alborz and the Zagros foothills which have an elevation of 1,000 to 1,500 m., probably approaches the country's average. In other sections, the mean annual precipitation is much higher than this average on the high mountains and also along the Caspian Sea and much lower in a major part of the interior as well as all along the southern seas.

The extremes of annual precipitation are found in Pahlavi, on the Caspian shore, which has an annual average rainfall of 2,089 mm., or five times the average for the country, and Mirjaveh, a railway station on the Irano-Pakistani frontier, with an average annual rainfall of 33 mm. only which is less than one twelfth of the country's average.

Seasonal Distribution of Precipitation

In the discussion of seasonal distribution of precipitation that follows, seasons are considered according to the Iranian calendar, i. e. with the year beginning on the first day of spring (March 20th) and each season covering three calendar months.

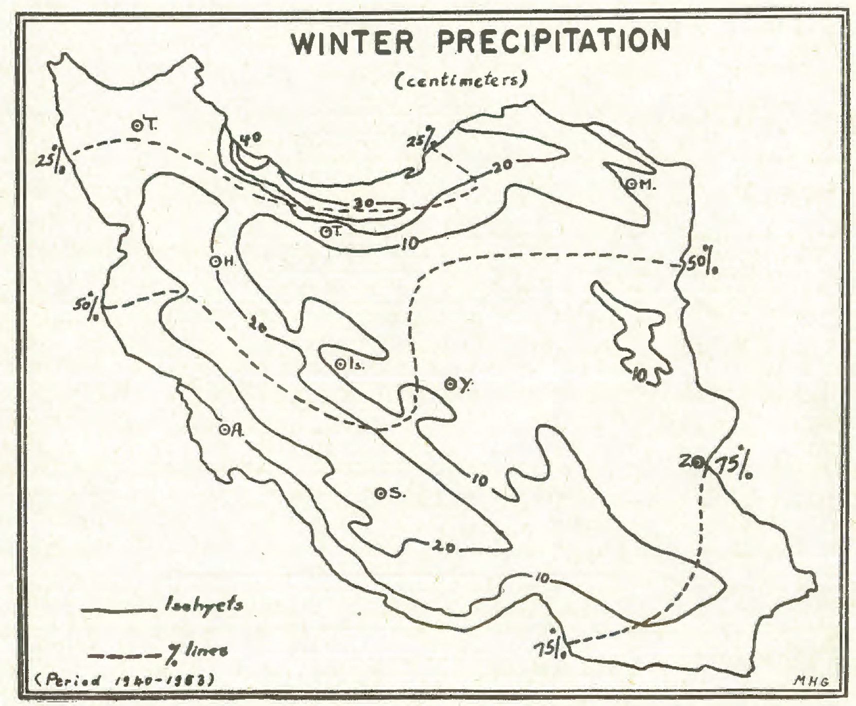
The seasonal maps which are to be discussed shortly are based on hitherto unpublished data except for two stations on the Persian Gulf and the Sea of Oman coasts, namely Bushehr and Jask, for which monthly data have been taken from other sources. In addition to seasonal maps of actual distribution of precipitation, percentage seasonal maps have

been also perpared to illustrate the time of maximum rainfall at various groups of stations. These are based on the proportion of the annual precipitation occuring in each season of the year and should prove to be helpful in explaining the actual seasonal distributions.

Finally, it should be noted that the term precipitation has been preferred throughout this discussion because all maps are based on figures that include both rainfall and snowfall.

Winter Precipitation

It can be said without any hesitation that winter is the rainy season of Iran for, although there are stations that receive their maxima in



Map No. 13 : Winter Precipitation.

spring or autumn, it is during the winter months that more than two thirds of the surface area of the country receive more than half of their annual precipitation (see map No. 13). This statement may appear

paradoxical if one examines the actual winter precipitation but the truth becomes evident when one remembers that the average annual precipitation for these parts of Iran is not more than 120 to 180 mm.

The percentage value of winter precipitation decreases from south to north. There are in the southern sections of Iran places that receive as much as 75 %, or even more, of their annual precipitation during the three winter months, as can be seen from the following table;

Percentage winter precipitation at selected stations

STATION	annual precipitation	winter precipitation	% of annual
Fasa	295 mm.	224 mm.	75
Khash	121 mm.	100 mm.	82
Zahedan	76 mm.	62 mm.	80

The following table gives further examples of more northern stations;

Winter precipitation at selected stations

STATION	Ann. prec.	winter prec.	% of total	years of observ.
Bushehr	246 mm.	129 mm.	53	43
Shiraz	336 mm.	222 mm.	66	13
Isfahan	166 mm.	80 mm.	50	13
Zabol	83 mm.	57 mm.	68	13
Kerman	168 mm.	105 mm.	62	12
Kermanshah	332 mm.	173 mm.	52	5
Ahwaz	190 mm.	99 mm.	53	11

The percentage lines on the map of winter precipitation brings out some interesting facts regarding stations in the high Zagros and the Alborz regions. It appears that the percentage value decreases as one goes further north and up the higher elevations, with the result that all the highlands of northern Khorassan and the southern foothills of the Alborz, as well as ths southern half of Azarbaijan, and the Zagros,

down to the neighborhood of Isfahan, receive between 25 % to 50 % of their annual precipitation in the winter months. The percentage value for the winter rainfall is at its minimum along the southern shores of the Caspian Sea and the northern half of Azarbaijan. Stations in these areas receive less than 25 % of their annual precipitation in the three winter months.

Winter precipitation at selected stations

STATION	Ann. prec.	winter prec.	% of total	years of observ.
Arak	331 mm.	140 mm.	42	13
Fariman	267 mm.	114 mm.	43	12
Hamadan	404 mm.	117 mm.	29	13
Maragheh	368 mm.	154 mm.	42	11
Tehran	226 mm.	110mm.	48	13
Rezaiyeh	427 mm.	140 mm.	32	11
Ardabil	262 mm.	87 mm.	33	10
Ramsar	1.196 mm.	206 mm.	18	13
Gorgan	1.154 mm.	245 mm.	21	12

Turning now to the winter precipitation map itself, we note that the striking feature of the map is the great extent of territory that receives less than 200 mm. of rainfall during the season. This covers almost the entire area of the country with the exception of the Caspian littoral and the higher sections of the two mountain systems. It has already been stated that winter is the rainy season for Iran and therefore one needs to glance at the winter precipitation map and appreciate the degree of aridity that prevails in the country. This is the season during which Iran gets most of its annual precipitation and yet, on the map, half the land surface of the country lies within the 10 cm. isohyet and more than two thirds of the remainder, between this and the 20 cm. line.

The wettest part of Iran during the winter months, is the Caspian region although it has been already indicated that this blessed section actually receives less than 25 % of its annual precipitation during this

season. Within the Caspian region itself, precipitation decreases from west to east as can be seen from the following table;

Winter precipitation at selected Caspian stations

STATION	Precipitation
Pahlavi	519 mm.
Lahijan	403 mm.
Ramsar	206 mm.
Nowshahr	217 mm.
Shahi	242 mm.
Gorgan	245 mm. (elevation 116 m.)

Next to the Caspian area and the northern flanks of the Alborz, come the Zagros highlands with a winter precipitation of over 20 cm. Precipitation over the very high sections must be well over 30 cm., especially in view of the heavy snows that fall at this time of the year, but in the absence of any data on higher elevations, it is not easy to make conclusive statements.

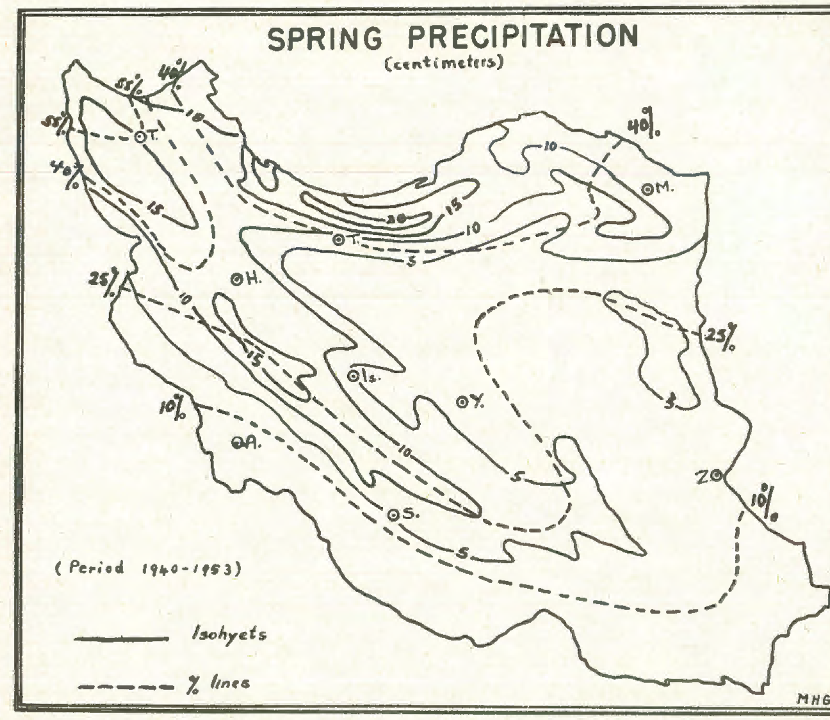
In Azarbaijan, the average winter precipitation is below that of Zagros and no station records a winter fall of more than 20 cm., but even there, the snow clad mountains of Sahand and Sabalan receive higher precipitation and therefore stand out on the map as islands of heavier rainfall.

The rest of the country is relatively dry even in the midst of its rainy season and the driest part is probably the Dasht-e-Lut, to the east of Kerman, but unfortunately no information is available regarding the precipitation amount in this desert.

Spring Precipitation

The spring season is the period of retreating Mediterranean depressions that, during winter, frequent the country. The average number of depressions that enter Iran from the west during the winter months (January to March) is 25 and the corresponding number for spring (April and May) is 12 which indicates that, on the whole, cyclonic activity is reduced by at least 50 % during the rainy spring months. Furthermore, it seems logical to assume that during the spring months,

depressions are weaker and therefore less able to penetrate far into the interior of the country. On the other hand, with the advance of spring temperature all over the country rises rapidly and the rise in temperature produces a great deal of convectional rain and thunder shower



Map No. 14 : Spring Precipitation.

over the snowclad highlands to the west and north of the country. The combined result of the above factors is that precipitation decreases considerably in the extensive lowlands of the eastern and southern Iran where maximum rainfall occurs usually in winter.

The percentage map of spring precipitation (map No. 14) indicates that all along the Persian Gulf coast the total spring precipitation is less than 10 % of the annual total which means that summer conditions already prevail over large portions of the southern coastal areas. Beyond the 10 % line on the map, lies the whole length of the central desert

as well as the hilly parts of Kerman, Fars and western Zagros in which areas, the aggregate spring rainfall varies from 10 to 25 % of the annual total.

On map No. 14 that also shows the distribution of spring precipitation, the 5 cm. isohyet line coincides almost exactly with the 25 % line of the percentage map for the same season. On the latter map, it is of interest to note that the percentage of spring precipitation increases from southeast to northwest but falls off to the north and the south in the coastal areas. Over the highlands of the eastern Zagros as well as on the southern foothills of the Alborz and northern Khorassan, where snow still lingers during the early spring months, there is considerable convectional rain with the result that stations located in the above mentioned areas receive between 25 to 50 % of their annual precipitation during the spring months. More interesting is the high percentage of spring rainfall exhibited by three stations to the northwestern corner of Azarbaijan where convectional activity may be considered at its height during this season.

Spring is a transitional season during which the high pressure center over Asia begins to weaken and, as the season advances, the easterly and northeasterly winds that prevail over the Caspian Sea throughout the winter months, become weaker and weaker. Consequently, rainfall along the Caspian shores of Iran falls to 10 % of the annual total which is quite comparable to the conditions prevailing along the southern coastal areas (Persian Gulf), ~~at least~~, as far as proportions are considered.

In spite of this drastic fall in the percentage value, the Caspian littoral is the wettest part of Iran in spring months. As in winter, precipitation decreases from west to east along the coast plain.

Outside the Caspian area, Azarbaijan enjoys a relatively wet period, especially in its western half, thanks to the considerable amounts of convectional rain around the Lake Rezaiyeh. Rains of this type occur over the higher Zagros too most of which is still under a thick blanket of snow in the early months of spring. Over the rest of the country dryness prevails and only occasional showers break the monotony and help growth of the short lived natural vegetation.

The following table will serve to illustrate the general conditions of spring precipitation at some stations;

Spring precipitation at selected stations

STATION	An. prec.	Spring prec.	% of total	years of observ.
Pahlavi	2,089 mm.	212 mm.	10	5
Ramsar	1,169 mm.	133 mm.	11	13
Shahi	618 mm.	91 mm.	15	8
Gorgan	1,154 mm.	166 mm.	14	13 [1]
Ahar	369 mm.	188 mm.	50	7
Khoy	347 mm.	192 mm.	56	12
Marand	311 mm.	162 mm.	52 [2]	?
Sanandaj	430 mm.	177 mm.	38	11
Hamadan	404 mm.	152 mm.	38	13
Arak	331 mm.	123 mm.	38	13
Tehran	226 mm.	57 mm.	25	13
Mashad	208 mm.	69 mm.	32	12
Quchan	368 mm.	146 mm.	39	3
Isfahan	166 mm.	49 mm.	30	13
Shiraz	336 mm.	52 mm.	15	13
Ahwaz	190 mm.	14 mm.	7	11
Bushehr	246 mm.	9 mm.	3	43
Jask	120 mm.	6 mm.	5	28
Zabol	83 mm.	16 mm.	20	13
Zahedan	76 mm.	9 mm.	12	7

[1] Note the decrease from west to east along the Caspian littoral.
[2] Note the high percentage in northeast Azarbaijan.

Summer Precipitation

Summer is a dry season all over Iran except in the Caspian area. With the onset of the summer heat, which in many places makes itself felt as early as in April, Iranians begin to shift their living from winter to summer conditions. During the winter months, the south facing rooms that benefit more from the warm rays of the sun, are made dwelling places. Iron stoves or other heating devices are set up and heavy clothings and covering used. As soon as the warm season shows its signs, a sudden change takes place in the domestic life of the inhabitants.

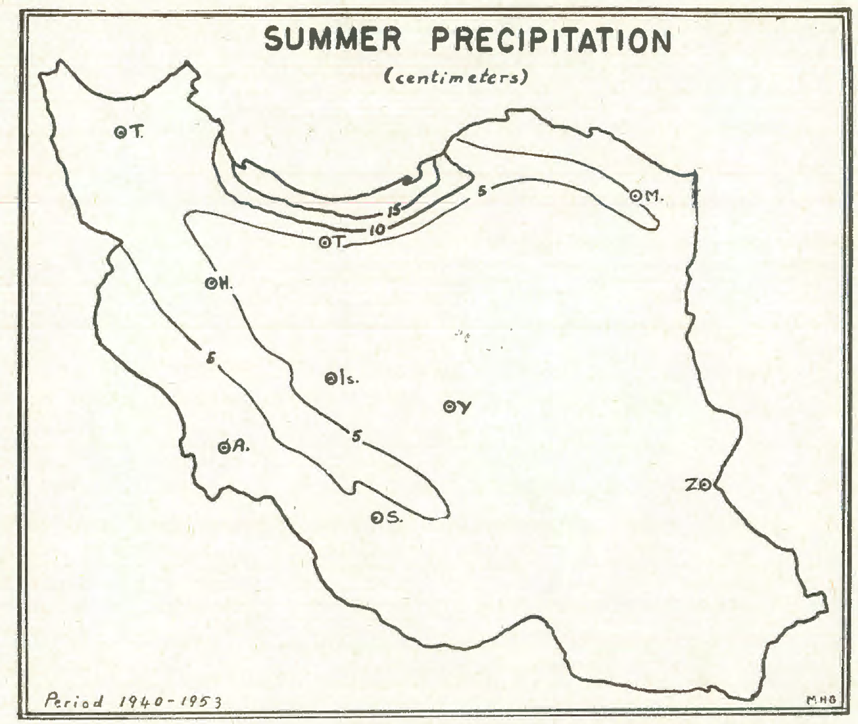
Those who can afford to, change their habitat to the more shaded and northfacing rooms where more protection from the scorching rays of the sun is secured. All winter clothing and covering are packed away, not to be used for six to seven months. «Badgirs» or wind-catchers, so characteristic of the Iranian architecture, are opened in all living quarters [1]. Dry and cool cellars, sometimes very deep in the more southern sections, are turned to regular daytime dwellings. Beddings are transferred outdoors for use throughout the summer. During this period, nobody would dream of spending a night indoors.

All through the long summer there is no risk even of a shower at many places in the interior of the country where clear skies are generally the rule. Over the hills, however, an occasional shower of very short duration may break the monotony. Many stations in the Zagros, Azarbaijan and the north Khorassan highlands record such occasional rainfalls which for the whole season amount to 5 cm. or thereabout. The chance for summer showers, outside the Caspian, appears to be more in northern and western Azarbaijan, where some stations receive as much as 6 % of their annual rainfall during the three summer months (see table below).

To the north of the Alborz, however, different conditions prevail and as soon as one crosses this all important mountain barrier, one finds a totally different world. In contrast to the desolate and barren scenery and absolute dryness to the south, one finds on the northern slopes luxurious forest, green fields and, above all, frequent rainfalls. The summer rains of the Caspian littoral are all orographic in nature. They are mostly due to the local winds or sea and land breezes that bring moisture from the extensive water surface and produce copious rain when forced to rise up to 3,000 m. altitude in short horizontal distances. Summer rains are regular and a matter of daily occurance at many stations along the coastline and the northern foothills of the Alborz.

[1] Badgirs are shafts, in the walls of the dwellings, that let the air enter the rooms and produce some ventilation. They are built so as to face the direction of the prevailing winds, sometimes about 20 feet above the roof of the house in order that they may catch more wind. They are usually closed at the beginning of the cold season but are a great relief in the hot summer months.

Some stations receive as much as 25 % of their annual rainfall during the summer months. In fact the amount of rain that some stations receive during the summer is higher than, and many times as much as, the rainiest of stations over the plateau receive in the whole year.



Map No. 15 : Summer Precipitation.

In summer the southwest corner of the Caspian is the wettest section of the coastal area (see map No. 15). Pahlavi receives 482 mm. (24 % of its annual amount) or more than the average for the whole country, in the three summer months. No information is available regarding the amount of precipitation received by the hillsides that surround the coastal plain in the south but the amount must be considerably more than what the coastal stations record. With our present knowledge of the conditions which prevail over the higher grounds, all information shown on precipitation maps should be considered tentative in nature.

Beyond the delta plain of Sefid Rud, in the southwestern corner of the Caspian, precipitation decreases as one goes north or east as can be

seen from the following table which shows selected stations over the whole country.

Summer precipitation at selected stations

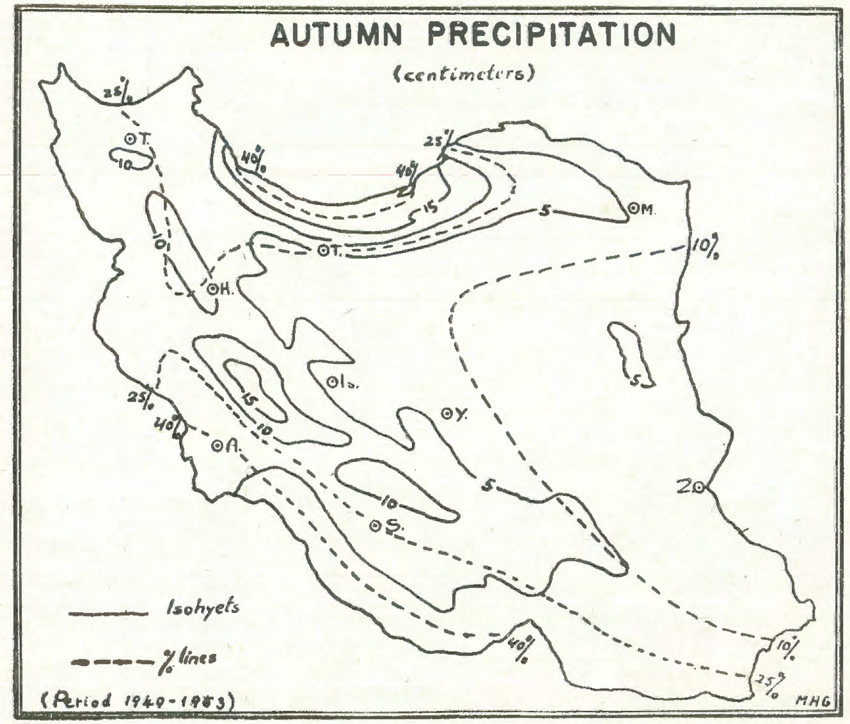
STATION	An. prec.	Summer prec.	% of total	years of observ.
Astara........	1,362 mm.	237 mm.	17	11
Pahlavi.	2,089 mm.	483 mm.	24	5
Ramsar.......	1,169 mm.	247 mm.	20	13
Shahi...... ...	618 mm.	68 mm.	10	8
Gorgan.	1,154 mm.	326 mm.	20	9
Ahar..........	369 mm.	20 mm.	7	7
Khoy..........	347 mm.	24 mm.	7	12
Marand........	311 mm.	16 mm.	6	?
Tabriz.........	283 mm.	16 mm.	7	12
Sanandaj......	490 mm.	4 mm.	1	11
Hamadan.	404 mm.	4 mm.	1	13

Autumn Precipitation

The Mediterranean depression to which Iran owes most of its annual rainfall, especially in the interior, are least active during the summer months but as soon as the shift in the general pattern of the world's atmospheric pressure begins, after the autumnal equinox, the depressions begin to make themselves felt over the Middle East and by mid-October some of them get sufficient strength to reach the western portions of Iran and the Persian Gulf areas. As time goes on their frequency becomes greater and they are able to influence more and more of the western half of Iran during the fall months. The Zagros and the Azarbaijan highlands as well as the Persian Gulf coasts draw more benefit from the autumnal cyclonic activities than the rest of the plateau country. Needless to say that over these areas orography plays a great part in giving higher grounds a more plentiful precipitation.

Another region that receives a very considerable amount of precipitation during the autumn months, is the Caspian littoral. In fact it is in this season that the Caspian area receives its maximum seasonal rainfall. Here again the rainfall is mainly cyclonic and the depressions reach the southern Caspian area and travel beyond into the northern Khoras-

san along the various tracks. During the autumn months, cyclonic activity along the northern track that by passes the Anatolian plateau and follows the southern parts of the Black Sea, is by far greater than over the southern track that eventually reaches Iran from the west.



Map No. 16 : Autumn Precipitation.

Weikmann has given the total number of autumnal depressions along the northern route as 35 whereas his figure for the southern track during the same season is 16. Besides, with the gradual formation of the Asiatic high pressure system, the area attracts easterly and northeasterly winds that pick up considerable moisture during their passage over the Caspian Sea. Furthermore, land and sea breezes blow regularly as in other seasons and, it is the overlapping or combination of cyclonic influences from the west, moisture bearing winds from the north or northeast, and local winds, that produce the autumnal maximum at all stations along the Caspian coastline.

Needless to say that during autumn, as in other seasons of the year, the Caspian littoral is the wettest part of the country. The autumn precipitation map, No. 16, brings this out clearly. It is interesting to note that again, rainfall decreases from west to east. The autumn precipitation percentage map, No. 16, is in close conformity with the facts already indicated about the rainfall of this region. The map shows that some stations along this coast receive as much as 50 % of their annual rainfall during the three autumn months. However, the proportion decreases as one travels eastward along the coast. The eastern sections are farther afield as far as the cyclonic influences are concerned. They are crossed by the easterlies before the latter have reached the sea. These winds which bring rain to the western sections, blow over the eastern parts as dry winds that bring nothing but clouds of dust at times. Consequently, stations like Ashuradeh and Gorgan not only record lower annual precipitation than the western stations, but receive only 25 % of their total annual rainfall during the autumn, i. e. the season when more western stations show a clear seasonal maximum.

The following table will serve to illustrate the precipitation conditions in the Caspian area. In the table, stations are arranged in their longitudinal position from west to east so that comparison of various columns may better bring out the general deterioration of rainfall conditions from west to east.

Seasonal precipitation at all stations in the Caspian littoral

STATION	annual prec. mm.	winter prec.		spring prec.		Summer		Autumn	
		mm.	% of total	mm.	%	mm.	%	mm.	%
Astara	1,362	304	22	335	24	237	17	286	37
Pahlavi....	2,089	519	26	212	10	482	24	876	40
Rasht.....	1,108	582	34	165	15	213	20	348	31
Lahijan ...	1,324	403	30	188	14	270	20	467	36
Ramsar ...	1,169	206	18	133	11	247	20	610	51
Shahsavar .	1,511	417	27	112	7	159	11	823	55
Nowshahr .	1,167	242	20	151	13	286	24	488	43
Babol.....	947	317	33	98	10	206	22	326	35
Ashuradeh.	467	114	25	76	15	162	35	115	25
Gorgan....	1,154	245	21	166	14	326	20	417	37

Of all the stations along the Caspian coast, two, namely Rasht and Ashuradeh present discrepancy in having winter and summer maxima respectively. All other stations exhibit a clear autumn maximum. The records for Rasht are for five years only and it is likely that over a longer period of observation this station will show more harmony with the rest of the Caspian stations. The figures for Ashuradeh have been taken from Bobek's work and the duration of observation is not known.

Outside in the Caspian littoral the autumn precipitation decreases both in the actual amount and in the percentage of the total. Some stations along the western foothills of the Zagros as well as in the eastern of Azarbaijan, appear to receive between 25 % to 40 % of their annual precipitation during the autumn months. Over most of the Zagros and the northern highlands of Khorassan, the amount and the percentage of rainfall are in close harmony. Most stations in these sections of the country receive 10 to 25 % of their annual total during the season in question, and as one goes south the percentage value increases but the actual amount, however, shows signs of decline due to the meagerness of the annual precipitation along the Persian Gulf coastal areas. The driest part of the country during this season is in the east where the few existing stations record as little as 10 %, or less, of their annual rainfall in autumn. This is perhaps because the depressions of this season are not yet strong enough to travel far and reach the eastern sections of the country. Besides, the eastern sections of Iran are characterized by more uniform topography and few prominent high mountain ranges. They are comparatively low in altitude. On the precipitation map for autumn, this area is left blank and on the whole receives less than 5 cm. of rain throughout the autumn months.

(*See on page 66 table illustrating precipitation conditions at selected stations*).

Autumn precipitation at selected stations outside the Caspian

STATION	ann. prec.	autumn prec.	% of total	years of observ.
Khoy	347 mm.	61 mm.	17	12
Hamadan	404 mm.	74 mm.	18	13
Arak	331 mm.	68 mm.	21	13
Tehran	226 mm.	59 mm.	27	13
Isfahan	166 mm.	37 mm.	20	13
Mashad	208 mm.	36 mm.	18	12
Shiraz	336 mm.	62 mm.	19	13
Bushehr	246 mm.	108 mm.	44	43
Jask	120 mm.	40 mm.	33	28
Zabol	83 mm.	10 mm.	12	13
Zahedan	76 mm.	5 mm.	8	7

Forms of Precipitation and Rainfall Provinces of Iran

Three forms of rainfall are generally recognised by climatologists; convectional, cyclonic and orographic, but these are by no means sharply separated one from the other. In fact, they often merge into each other to such an extent that one can hardly venture to assign a certain proportion of the annual rainfall of a station to one or another form of precipitation. Nevertheless, some general remarks may be made regarding the approximate predominance of each form in Iran.

It can be said at once that most of the winter rain, which is more widespread than that of other seasons, has its origin in the Mediterranean depressions and is therefore cyclonic in nature (43 out of 65 stations with rainfall record, show a winter maximum). This indicates that in most of the country precipitation is cyclonic. In fact, if a line be drawn from Sarakhs, in the northeastern corner of the country to Abadan in the southwest, it will be seen that the territory south of this line receives 60 % to 75 % of its annual precipitation during the winter months (December 20th to March 20th). Stations with spring or fall maxima also benefit a great deal from the winter cyclonic rains as they receive a considerable proportion of their annual fall during this season.

Convectional rains occur mostly in spring when longer days and bright sunshine produce considerable heat over the earth surface, and result in expansion and rising of the adjoining air layer. Convection is greater in the mountainous and highland sections where solar radiation is more intense than in the lower areas, and where there is great reflection of heat over snow covered surface of the ground [1]. The melting of snow also helps to increase the moisture content of the air that is in contact with the ground. On the other hand, in the upper layers of air colder temperatures still prevail with the result that when moist air from near the surface rises due to heating and expansion, condensation takes place at comparatively low altitudes above the ground. Thunder showers are typical convectional rains and are common to most of the higher grounds of Iran during April and May. These are considered most important for the rain agriculture of Iran as they occur during the growing season and at a time when they are needed by the plants [2].

Convectional rains are of short duration but they can be exceptionally violent and disastrous on occasions. They occur mainly in the afternoons or early in the evenings, on the days when the morning temperatures rise to levels higher than the average. They sometimes change to hailstorms which are more dangerous to the human and plant lives.

Orography is a major factor in the distribution of precipitation in Iran and its influence can be seen on all rainfall maps and should be emphasized in any climatic study of the country. Relief of the land becomes an important factor in the climate of any region when highlands or mountain ranges lie across the paths of prevailing moist winds. Iran is therefore an excellent example where orography enters the picture as a determining factor in climate. The parallel ridges of the Zagros range, with a general NW-SE trend, are in the way of the prevailing westerlies of the winter season.

(1) Hann (H.), *Handbook of Climatology,* translated by R. D. Ward Part I, New York 1903, p. 231.

(2) Bobek (Hans), *Die Verbreitung des Regenfeldbandes in Iran, Geographische Studien,* Geogr. Inst. der Universitaet Wien 1951.

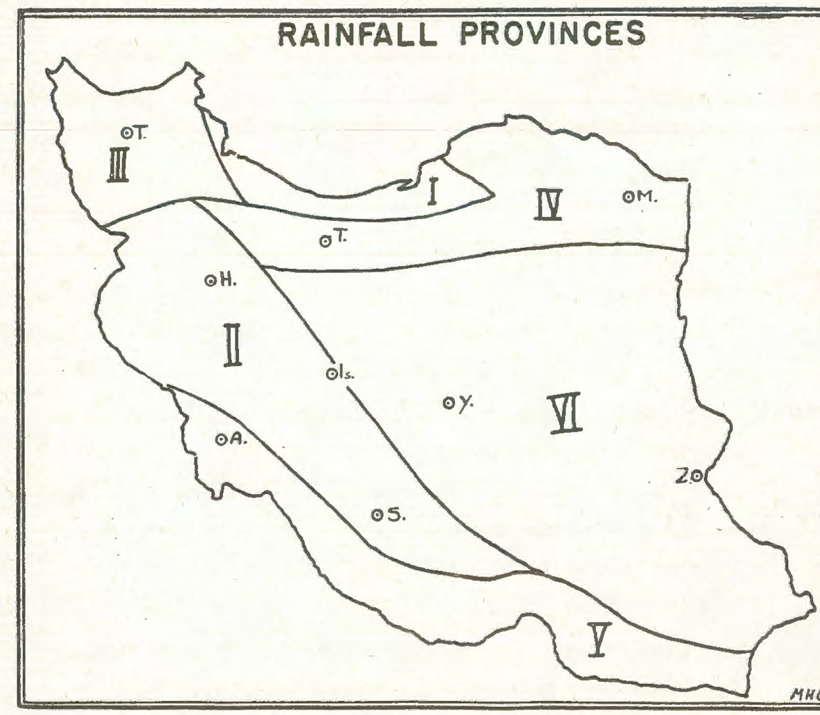
The best examples of orographic rains in Iran are to be seen along the southern shores of the Caspian Sea or the northern foothills of the Alborz mountains. Here the mighty ranges that rise almost abruptly from below sea level to heights of over 3,000 m., produce formidable barriers in the way of the easterly and northeasterly winds from the heart of Asia. The winds that blow over the Caspian, excepting those that blow from the east, are invariably dry in origin but on their passage over the sea they pick up sufficient moisture and therefore, on their ascent over the northern flanks of the Alborz, they produce considerable rain. To the southwest of the Caspian, the Talesh range runs from north to south almost at right angles to the direction of the easterlies that before ascending the slopes, have traversed the entire width of the Caspian. Here is Pahlavi, with a record of annual fall of 2,089 mm., the highest in Iran. Further east along the Caspian shores, precipitation decreases as the mountains become more or less parallel with the direction of the prevailing winds. Consequently, the annual rainfall drops to 947 mm. in Babol and even 618 in Shahi but Gorgan, further east at an elevation of 116 m. receives 1,154 mm. annually.

For the purpose of analysing the annual precipitation of the country it appeared advisable to adopt some sort of a regional grouping of stations that would correspond to the composite temperature curve discussed in another section. Consequently, stations with common characteristics in rainfall regime were grouped together to form rainfall provinces. Such provinces or zones will be dealt with here, in order of the amount of annual precipitation, e. i. leading from the wettest to the driest province (see map No. 17).

1. *The Caspian Littoral.*

The ring of territory that encircles the southern shores of the Caspian Sea is by far the wettest part of the country. The region, as far as the rainfall is concerned, comprises all of the coastal plain plus all the northern slopes of the Alborz up to the crest of the middle range, and even, as far south as the watershed of the southern ridges that overlook the dry plateau to the south. To the north of these crests rainfall is plenty

throughout the year. Great humidity, more moderate temperatures, cloudiness and forest vegetation characterize the province. The whole area except the narrow coastal plain is covered with luxurious subtropical forest which presents a pleasant picture so different from the desolate and barren wastelands that lie to the south of the mountains.



Map No. 17 : Rainfall Provinces of Iran.

In this respect the Alborz range probably forms one of the most formidable climatic barriers in the world. The geographical influence of this mountain barrier is so great that one can hardly find a transitional zone between the green slopes to the north and the barren ones to the south of the Alborz.

The Caspian littoral receives, on the average, more than 1,000 mm. of rain which is about three times that of the country as a whole (416 mm.) and twenty or more times higher than that received by some

stations in the interior of the country. The available data portrays the rainfall conditions for the coastal areas only and the amount of precipitation on the higher elevations of the first and northern ranges, that get the maximum benefit of the orographic rains, must be well beyond two metres a year.

Along the coast the total precipitation decreases from west to east as can be seen from the following table :

Mean annual precipitation at Caspian stations

STATION	amount
Pahlavi	2,089 mm.
Rasht	1,108 mm.
Lahijan	1,324 mm. (elevation 20 m.)
Ramsar	1,196 mm.
Shahsavar	1,511 mm.
Nowshahr	1,167 mm.
Babol	947 mm.
Shahi	618 mm.
Ashuradeh	467 mm.
Gorgan	1,154 mm. (elevation 116 m.)

2. *The Zagros Highlands.*

Next to the Caspian littoral, although far behind it in the total annual rainfall, is the belt of highland that covers most of the western and parts of southern and central Iran. Throughout this extensive belt, land configuration is probably the most important factor in the distribution of precipitation which occurs mostly in the form of snow on higher grounds. There are altogether 25 climatic stations in this extensive belt of highland and they are located between 1,300 and 1,880 m. contour lines. The data available apply to the land below this altitude and, unfortunately, make no allowance for the snow that falls above this level. The averages referred to here relate to the more inhabited and lower parts of the highlands.

Among the stations included in the Zagros Highlands, the following can be considered as typical of the whole area :

Average annual precipitation at selected stations in the Zagros highlands

STATION	Elevation	Precipitation
Arak	1,880 m.	331 mm.
Bijar	1,590 m.	521 mm.
Borujerd	1,670 m.	531 mm.
Hamadan	1,860 m.	404 mm.
Kermanshah	1,472 m.	332 mm.
Malayer	1,817 m.	269 mm.
Sanandaj	1,648 m.	490 mm.
Khorramabad	1,310 m.	823 mm.

The average annual precipitation for the entire area included in the Zagros Highlands is 462 mm. which, although far below the average given for the Caspian Littoral, is above the country's average of 416 mm.

3. *The Azarbaijan Plateau.*

The province of Azarbaijan, which comprises the northwestern portion of Iran, receives less abundant precipitation than the section just discussed. During the cold months of the year, Azarbaijan is dominated by a tongue of high pressure that extend over Armenia and Anatolia. It is, furthermore, surrounded by high mountains that block all maritime influences of the Caspian Sea from the east and, at the same time, reduce frequent penetration of moisture bearing winds from the southwest. Cyclonic rains of the winter season therefore effect this region much less than the Zagros Highlands which are in the direct path of the Mediterranean depressions. However, this province receives more convectional rain in spring and early summer months. The Moghan steppe to the northeast of the province is the driest part with almost desert conditions, whereas the higher grounds around the volcanic peaks of Sabalan and Sahand, with plenty of snow, constitute the wettest parts of the province.

The following table of annual precipitation at selected stations over the plateau will serve to illustrate the general conditions prevailing in this rainfall province of Iran :

Average annual precipitation at selected stations in Azarbaijan

STATION	Elevation	Precipitation
Ahar	1,459 m.	360 mm.
Ajabshir	1,400 m.	395 mm.
Ardabil	1,570 m.	262 mm.
Khoy	1,370 m.	347 mm.
Maraghah	1,400 m.	368 mm.
Marand	1,462 m.	311 mm.
Rezaiyeh	1,300 m.	427 mm.
Shahabad	80 m. app.	346 mm. (3 years average only)
Tabriz	1,360 m.	283 mm.

The mean annual precipitation for the region as a whole is 345 mm. which is below the average for Iran.

4. *The Southern Alborz and North Khorassan Mountains.*

The southern slopes of the Alborz exhibit dryness when compared with the more fortunate north facing slopes and aridity in this part of the country becomes more prominent when one considers the conditions prevailing only a short distance to the north. Nevertheless, the region, as a whole, receives somewhat heavier precipitation due to higher altitude and therefore deserves being classed separate from the rest of the interior. The basins and ranges of Northern Khorassan have many aspects in common with the southern Alborz to the west and the two regions can be fittingly classed together, in the form of independent rainfall province that extends all the way from the neighbourhood of Qazvin, in the west, to the frontiers of Afghanistan, in the east. However, in its western extension, the province includes a very narrow belt for the desert begins not very far from the lower reaches of the Alborz. In the east, on the other hand, it widens to include almost all the territory that lies to the north of the Tehran-Mashad highway.

Precipitation is low over all this area as can be seen from the following table. Most of the stations record no rainfall for at least five months in the year. Also, the snowfall is not as plentiful and lasting as in the western sections of the country.

Average annual precipitation at selected stations in Southern Alborz and Northern Khorassan

STATION	Elevation	Precipitation
Karaj	1,300 m.	238 mm.
Tehran	1,200 m.	226 mm.
Takistan	1,253 m.	327 mm.
Sabzevar	1,005 m.	167 mm.
Mashad	940 m.	208 mm.
Fariman	1,380 m.	267 mm.
Quchan	1,252 m.	368 mm.

The average for the entire area, on the basis of the above mentioned stations, is 242 mm. which is not very much more than half the country's average of 416 mm.

5. *The Persian Gulf Coast.*

In this division is included the whole of the lower plain of Khuzistan together with a narrow belt of land running parallel with the coast line all the way to the borders of Pakistan. Unlike the coastal plains of the Caspian Sea the districts that adjoin the Persian Gulf and the Sea of Oman are very dry. There is, however, one aspect that makes this area distinct from the dry interior. That is the high relative humidity which prevails practically all over the southern coasts of Iran.

Rainfall is very moderate all along the southern shores and coastal districts of Iran as can be seen from the following table :

Average Annual Precipitation at selected stations in the Persian Gulf coastal area [1]

STATION	Elevation	Precipitation
Abadan	6 m.	169 mm.
Ahwaz	66 m.	190 mm.
Bushehr	10 m.	246 mm.
Darab	1,210 m.	170 mm.
Jask	4 m.	111 mm.
Fasa	1,375 m.	295 mm.
Jahrom	1,010 m.	149 mm.
Iranshahr	593 m.	117 mm.

The average for the entire division is 180 mm. which is below the average for the country. A greater portion of the annual rainfall is received during the winter and many stations record no precipitation whatever for six or seven months in the year.

6. *The Interior Deserts and Steppelands.*

All that remains of the country's land area is included in one large division which covers not only the deserts proper of the interior of Iran, but also all the highlands that lie to the east of the desert, as well as such parts of the central ranges and basins that are not included in the Zagros division. This wide area is characterized by dryness of the atmosphere and extreme aridity. Aridity is caused by long hours of sunshine and the consequent excessive evaporation, low elevation and uniform topography, as well as greater distance from the source of moisture that brings rain to the major part of western areas. The rain bearing winds that blow from the west over Iran during winter months, get rid of most of their moisture before they reach the interior of the country and are warmed up due to compression on their descend down

(1) Data for Darab, Fasa, and Jahrom are quoted from Hans Bobek; those for Bushehr and Jask come from *Smithsonian Miscellaneous Collections,* vol. 90, 1934, Washington, D. C.

the eastern slopes of the Zagros. They probably require to ascend to considerable heights before any rain can result and the eastern and interior parts of Iran lack such prominent mountain systems. Furthermore, as already indicated, it is likely that a tongue of high pressure dominates over the central deserts of Iran during the cold winter months. This local center of high pressure helps to block easy penetration of the Mediterranean depressions into the desert sections of the country. The above factors combined make this rainfall province of Iran one of the driest regions as can be seen from the following table :

Average Annual Precipitation at selected stations in the interior of Iran

STATION	Elevation	Precipitation
Isfahan	1,550 m.	166 mm.
Kerman	1,650 m.	168 mm.
Khash	1,507 m.	121 mm.
Qom	940 m.	98 mm.
Savah	1,100 m.	249 mm.
Varamin	940 m.	97 mm.
Yazd	1,220 m.	126 mm.
Zabol	516 m.	68 mm.
Zahedan	1,370 m.	80 mm.
Mirjavah	840 m.	33 mm. (After Hans Bobek)

The average annual precipitation for the whole area amounts to 120 mm. which makes a great portion of Iran comparable to some of the desolate desertlands of the world.

Chapter VI

CLIMATIC PROVINCES OF IRAN

The climate of any region results from the combination of various meteorological elements and consequently, there is an infinite variety of climates over the earth's surface [1]. In the classification of the world's climate any one, or any combination of climatic elements can be made

(1) De Martonne (E.), *op. cit.*, p. 229.

the basis for study. Hence there are many systems of dividing the earth into climatic subdivisions [1].

None of the systems of the world's climatic classification has so far been applied specifically to the area under study but, on some climatic maps of the world, Iran is treated in some detail, in spite of the fact that so little is still known of its climatology. The reason for the considerable attention paid to Iran is that the country forms the meeting place of a number of important climatic types whose boundaries extend into Iran. It is in Iran that the Mediterranean climate degenerates into various kinds of desert climates and, it is here, that the monsoon type of the Indian subcontinent approaches the desert climate of Arabia.

Of all the systems of climatic classification devised by various authorities that by Dr. Wladimir Koeppen of the University of Graz in Austria is probably the most important one now used by geographers and known as Koeppen System. During his brilliant career, the Austrian climatologist paid special attention to the question of climatic classification and revised his original scheme (first published in 1909) a number of times; his final analysis appearing in 1936 [2].

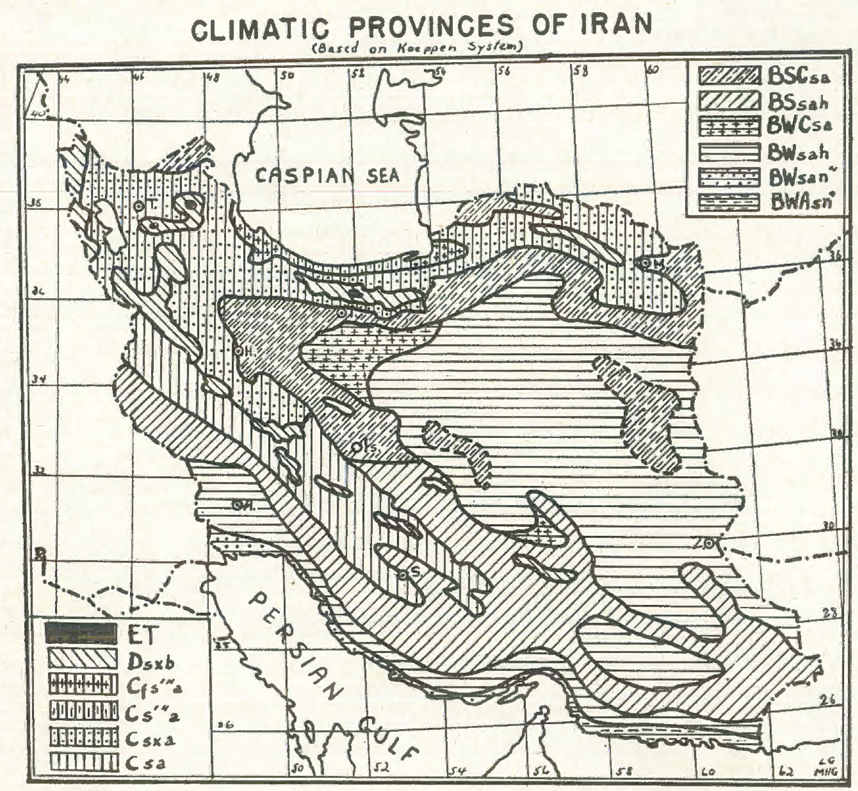
Koeppen's system is primarily based on mean annual and mean monthly values of temperature and precipitation and also their seasonal characteristics. He chooses certain numerical values of temperature and rainfall for determining the limits between various climatic types. Such values are selected mainly in relation to their effect on vegetation. Koeppen takes into consideration not only the mean annual temperature and the total annual precipitation, but also the temperature of the warmest and the coldest months and the season of maximum precipitation. He works out formulas based on the relationship between temperature and precipitation or, on their combined effects, to determine the boundaries between the wet and the dry and also between desert

(1) K. Knoch und A. Schulze, *Methoden der Klimaklassifikation,* Petermanns Geogr. Mitteilungen, Ergaenzungsheft, Nr. 249, 1952.

(2) *Das geographische System der Klimata,* vol. 1, part C of the *Handbuch der Klimatologie,* by Koeppen und Geirer, Berlin 1936.

and steppe climates. In addition, he gives separate formulas for the summer and winter concentrations of rainfall.

In view of the foregoing it was considered advisable that in the final chapter ot this study an attempt be made at bringing the results of



Map No. 18 : Climatic Provinces of Iran.

the previous chapters together in the form of a map of climatic provinces of Iran based on Koeppen's system.

In the construction of the accompanying map of climatic provinces of Iran (map No. 18) 56 stations were utilized. These were the stations for which the existing rainfall and temperature data were adequate to permit formation of a Koeppen symbol.

A glance at the map under consideration will make it clear that of the five major climatic groups of Koeppen's, four are represented in

Iran. It is only the A group or the tropical rainy climate which is missing on the map.

The boundaries between BW and BS, as well as those separating the BS from the C climates have been drawn on the basis of the evidence furnished by the stations. The boundaries of the D and E types have been drawn with the help of the contours of the land and, with due consideration of the normal lapse rate of temperature from the nearest station.

It should be added here that the two independent patches of BS climate, one in the center and the other to the east of the country, both surrounded by BW, have been drawn without any stations and simply on the basis of the writer's personal information about the eastern section and the general indication of relief and human habitation in the other.

B Climates

As a group B climates are Dry Climates, in which there is an excess of evaporation over precipitation. No surplus water remains, therefore to maintain a ground water level near the surface with the result that no permanent streams can originate in the areas that have a B climate [1]. Consequently, there is little ocean drainage and most of streams disappear in the interior [2].

From the description of drainage, rainfall, and evaporation in Iran included in the previous chapters, it will be easily understood that all the requisites for B climates are at hand in this country. It is therefore little wonder that the B climates form the dominant types on the climatic map of Iran. According to the estimates made by the present writer, after the accompanying map was prepared, of the total of 1,640,000 sq. km. surface area of Iran about 1,200,000 sq. km., or more than two thirds, are characterized by having one kind or other

(1) Trewartha (Glen T.), *op. cit.*, Appendix A.

(2) De Martonne (E.), *Regions of Inland Drainage, Geogr. Rev.*, 1927, pp. 397-444.

of the B climates. Of this total some 700,000 sq. km. has a BW or arid desert climate and the remaining 500,000 sq. km. is climatically classed as BS or semi-arid.

The BW Climate

The BW or desert type of Climate is found in two distinct sections of Iran, namely along the coasts of the southern seas and in the interior. Two distinct sub-types can therefore be recognized, each with characteristics of its own.

Along the southern coastal areas aridity, combined with high temperature and often very high humidity, prevails all the way from the borders of Pakistan in the east to the frontiers of Iraq in the west.

Temperatures are moderate to high throughout the year in the BW climate of Iran. This is more true of the annual temperatures for, during the cold winter season the interior of Iran is liable to record low temperatures. In the coastal BW areas an absolute minimum of -2° C has been once recorded in Ahwaz. At Bushehr, further south on the Gulf, the lowest record in 32 years is 0° C and in Jask nothing below 2° C has been recorded in 42 years [1]. At Ahwaz February is the coldest month with a mean value of 15° C whereas in Jask the mean for January which is the coldest month of the year is 19° C.

Summers are extremely hot. In Ahwaz, from which the highest record for the country comes, the mean for July is 36.2° with August being only 0.1° C lower in temperature. This monthly mean is also the highest for the country if we exclude the shortlived station at Iranshahr, that has recorded a July average of 36.9° C in five years. Further south along the coast the July mean temperatures are below that of Ahwaz but the high degree of relative humidity more than compensates the lower temperatures as far as human comfort and health are concerned.

Precipitation is very meagre in amount and extremely variable in occurrence. Whatever rainfall there is comes in the cooler winter months

(1) Reed (W. W.), *op. cit.*

(November to March) and there is no sign of rain for at least seven months a year. December and January are the wettest months and all stations tend to show a fair regularity in this respect however small the total annual rainfall may be.

An interesting feature of the climate of the Persian Gulf, which makes it unique among all climatic types of Iran, is the presence of fog. In fact, the narrow coastal belt along the Persian Gulf is the only section of Iran where the symbol n″ of Koeppen's can be used with any degree of certainty.

Outside the coastal areas of southern Iran the arid desert type of climate is found in the depression of Jazmurian (in Baluchistan), an extensive lowland basin with numerous salt pans, separated from the coasts and interior by two saddlelike ridges of higher ground that connect the eastern reaches of Zagros with the volcanic masses of Taftan.

The greatest extent of desert and the BW type of climate that is associated with it, is to be found in the interior of the country. The subdivision, earmarked «interior type» in the present study, deserves special attention from two points of view. In the first place, it has a very large domain which is undoubtedly larger than any other type of climate in Iran. In the second, the climate of the interior of Iran has received little attention and, in certain cases, it has been misrepresented.

The most important aspect of temperature of the desert stations, is its great daily range. This is no doubt common to most desert lands of the world and Iran can be no exception to the rule, but the reason why this point is indicated with some emphasis, is that, as far as the BW type of climate in Iran is concerned, this is the particular characteristic that differentiates between the interior subtype and the one along the coastal areas. In the latter subtype, neither the daily nor the annual ranges of temperature are as great as in the interior. At nights temperatures fall considerably in the interior because of rapid loss of heat, dry atmosphere and clear skies. The result is that although the day temperatures may be higher than the coastal station, monthly averages tend to be smaller. The highest monthly average of all the stations in the interior is 32.9° C which represents the July average for

Yazd (elevation 1,220 m.). This is below the mean for the same month in Ahwaz which is 36.2° C. However, when we consider the altitude factor in Yazd, we arrive at the conclusion that the lower sections of the desert must actually experience higher temperatures than the coastal areas.

Zabol, in the heart of a desert that extends from Iran into Afghanistan has an August average of 29.9° C but this station has recorded a maximum of 50° C in 13 years. Zabol has in fact recorded monthly maxima ranging from 46° to 50° C during each of the six months April to September and 41° in October. Even Kerman, at 1,650 m., has recorded 44° C in June, July and August and Qom, four and a half degrees of latitude farther north, has experienced 45° C in August.

Just as summers are hot in the desert sections of Iran, winters appear to be cold all over the area. Zabol with a January mean of 7.3° C has received temperatures as low as -11° C and at Kerman an absolute minimum of -16° C has been recorded. The absolute range of temperature during the period of the present study is 61° C for Zabol and 60° C in Kerman. The annual range of 27° C at Yazd is also one of the highest in the country.

Rainfall is very scanty and even less than in the coastal areas. For one station, namely Mirjavah, Bobek has given the negligible average annual of 33 mm., but the annual precipitation in the stations included in this section ranges from 83 mm. in Zabol to 168 mm. in Kerman. Most of the scanty rain comes in the winter months (January to March). There are some irregularities in Yazd and Qom whose records are of a shorter duration. In Zabol and Kerman which have 13 and 12 years of data respectively, December to April are the rainy months.

Beside being scanty, the rainfall in the BW type of climate in Iran is very variable from year to year as can be seen from the following table that shows annual and seasonal variability of precipitation at Zabol.

Variability of seasonal and annual rainfall in Zabol over thirteen years

Winter	66 %
Spring	100 %
Autumn	90 %
Annual	80 %

Out of a total of 14 stations in the BW type of climate in Iran, three, namely Varamin and Qom in the north and Kerman in the south, have annual temperatures that fall below 18° C. They therefore represent the BWC type and have been shown so on the map. The rest of the BW stations having all an average annual temperature above 18° C are marked as BW (h) on the map under consideration.

BS Climate

The BS or semi-arid steppe climate is often a transition between the arid deserts on the one hand and the more humid climates on the other. In Iran the BS surrounds the BW type on all sides except where the latter ends up at the coasts (see map No. 18).

The BS type of climate that altogether covers half a million sq. km. of Iranian territory can be aptly called a « Piedmont » type as in most cases it occupies the foothills of higher mountains. The area covered by this type of climate, except along the coasts of the Caspian Sea, lies generally between 1,000 and 1,500 m. contours, although there are exceptional cases where lands with about 2,000 m. in altitude are included in this type.

As a climatic type the BS is more widespread than any other type of climate in Iran. It can be found in the south, not very far from the sea of Oman at about 26° N latitude, and in the north, in the northernmost tip of Iran in northeast Azarbaijan (latitude 39° N). In its east-west extension it is similarly traceable on the frontiers of Afghanistan and Pakistan and again on the borders of Iran's western neighbour, namely Iraq.

In spite of its great size and widespread nature, the BS type of climate does not coincide with the most populous part of Iran and therefore does not offer a great number of climatic stations. There are no stations with any considerable length of observation in the east, nor in the southeast of the country and we must content ourselves with the study of stations in the west, central and northern sections only.

The BS areas of central and northern Iran are liable to experience extremes of temperature. In summer excessive heat results from the scorching rays of the sun whereas in winter cold air from central Asia

may influence the entire area at times. Tehran has recorded an absolute maximum of 44° C, Isfahan 41° and Mashad 43°, during the period used in the present study. However, it is from Mashad, which is nearer to the source of winter colds, that the lowest record of -25° C comes for the same period.

In all stations July is the hottest and January the coldest month. The annual range of temperature is great throughout the BS climate and varies from 25 to 27 degrees. However, more important than the annual range, from the point of view of human comfort and health, is the high daily range of temperature which is the chief feature of the BS climates of Iran.

Precipitation is, on the whole, meagre and variable in the BS as in the BW climates of Iran. Of the stations included in this section Dezful has the highest annual rainfall of 293 mm. and Isfahan the lowest (166 mm.). In the southern BS area of Iran, better defined as the BSA belt, precipitation occurs during the short winter season only. In Dezful or Kazerun there is no record of any precipitation from May to November. Here February seems to be the rainiest month of the year, although Dezful shows a second maximum in April and Kazerun a first maximum in November. However, as already pointed out repeatedly, such irregularities may eventually disappear as more data become available. This is generally more true in the case of precipitation than in the case of temperature. Precipitation is very variable and one unusual downpour of rain may alter the entire rainfall regime or precipitation at the station concerned.

In the northern and central parts of the BS, or in the BSC areas, precipitation extends over a longer period of time in spite of its small quantity. The number of rainless months is therefore reduced to five in Isfahan and Tehran, and even to four in Mashad. Generally speaking, the period November to May constitutes the rainy season but the amount as well as the regime varies from year to year at any one station. December and January, are the rainiest months in the western parts but, further east in Mashad, February and March come to the picture with some prominence. This station shows a clear second maximum in May which is due to convectional showers.

All through the BS climates of Iran precipitation is variable and highly undependable. This is a characteristic of the BW too but it is in the BS type that it becomes a real danger. The deserts of central Iran are mostly uninhabited but the surrounding steppes are not totally without population. There are many villages and even large towns such as Tehran (with more than one million and a quarter inhabitants), Isfahan, Mashad etc. in this climatic belt and therefore failure of rains prove to be catastrophic to the lives of local inhabitants.

The coincidence of rainy season with the period of low sun and low temperature means that precipitation effectiveness becomes much greater as far as natural vegetation of the steppeland is concerned. The winter rains find their way deep into the soil and are little evaporated, with the result that a new supply is added every year to the under ground water and is utilized in the drier and warmer months of the year. This is the most important point in the agricultural life of Iran in the BS climate. Besides, the winter rains prepare the ground for spring grasses that bloom as soon as the heat becomes adequate for plant growth in March or April. During these months the whole countryside is covered with a coat of grass that, in places, attain heights of a few feet. This is the case in the Turkeman and Moghan steppes in the north and in Khuzistan in the southwest of the country. In Kazerun the spring grass is so powerful that it grows on all mud walls of the houses and dwellings and nothing is more picturesque than seeing the walls and roofs of Kazerun houses covered with a profusion of spring flowers.

Natural vegetation over all the BS area of Iran is connected directly with the winter rains. In rainy years « spring is in », as the local inhabitants name the occasion. Everywhere the desolate land is covered with a green mantle of grass on which the pastoral people find their paradise. In years with no rain « spring does not call » and there is nothing exciting about the change in the season for the average Iranian farmer or stock raiser. In any case, as soon as the summer heat begins to make itself felt by May or thereabout, a sudden death overtakes the natural vegetation and, for ten more months, the steppe presents nothing but a monotonous and tiring sight of barrenness and desolation.

C Climates

Of the total land surface area of Iran about 400,000 sq. km., or one quarter, is dominated by the C or mesothermal group of climates. In Koeppen's system the C group is distinguished from the B and D groups by a special temperature characteristic. In the present study of the climate of Iran out of 56 stations with adequate rainfall and temperature data, 31 or more than half demonstrate the necessary qualifications for being included in the C group of climates. This is an indication that, generally speaking, the realm of C climates coincides with the most populous sections of Iran for it is because of greater concentration of population that a larger number of climatic stations are established on a relatively smaller area of land.

On the climatic map of Iran the C climates stand out distinctly in a V shaped form with one side of this letter running almost east-west along the northern territories of the country, and the other extending southeastward almost parallel with the western frontiers and the Persian Gulf coastline. As a group, the C climates therefore occupy all the higher levels of the Zagros, a major part of Azarbaijan, the entire length of the Alborz and the coastal plains of the Caspian Sea.

Within the limits laid down for the C climate there is great climatic diversity and therefore the area has to be broken down to smaller subtypes for the sake of detailed study. For instance, the Caspian coast shows great geographical contrasts when compared with the rest of the area dominated by C climates. Here the landscape, as well as human occupation and land use, vary so much from the rest of the country that the region deserves independent treatment. In the discussion that follows, therefore, first the highland sections of the country will be dealt with and then, the Caspian littoral will be treated as a separate unit.

C Climate (Highland type)

Although the various types of C climate are best distinguished by their Koeppen symbols, it is possible to recognize two major subtypes

and differentiate them by general geographical rather than purely climatic characteristics. Distinction can thus be made between the « Highland» type of C climate which dominates over most of the higher lands of Iran and the « Caspian» type which is limited to the coastal plains of the Caspian Sea and the mountains lying immediately behind them.

In another chapter of the present study devoted to the discussion of precipitation, it was pointed out that over most of the highland section of Iran, the meagre rainfall occurs during the cold winter months. It was also indicated that summers are generally dry and rainless. Consequently, the highland sections of Iran that have a C climate , fall almost entirely within the range of the Cs or summer dry climate. However, two variations of the Cs can be distinguished from the study of data available; Csa in the southern sections of the Zagros and Csxa in Azarbaijan and all along the Alborz ranges as far east as the northern highlands of Khurassan.

The Cs climate is usually regarded as typical Mediterranean climate. This is characterized by 1) a concentration of the modest amount of precipitation in the winter season, summers being nearly completely dry; 2) warm to hot summers and mild winters; and 3) a high percentage of possible sunshine in the year especially in summer [1]. Generally speaking, the above mentioned conditions exist in most of the highland sections of Iran where a major part of the annual precipitation falls in winter, summers are exceptionnaly hot and sunny and, more or less, dry. The only characteristic of the Mediterranean climate that does not find a counterpart in the Iranian highlands is the warm winter. In the highlands of this country winters are not only not warm, but can occasionally be very cold especially in Azarbaijan and Khurassan which are more exposed to the effects of cold waves from Russia. The protection offered here by the mountains is much less than that provided by the Alps in the case of most Mediterranean lands.

The following comparison between some typical Mediterranean stations and Iranian stations would illustrate the actual contrast in temperature of the two regions :

[1] Trewartha (Glen T.), *op. cit.*, p. 254.

Monthly temperatures at selected stations in the Mediterranean area and in Iran [1]

STATION	Mean Annual	J	F	M	A	M
Palermo.....	17.3	10.3	11.2	12.6	14.8	17.8
Athens... ...	17.6	8.6	9.4	11.9	15.3	20.0
Jerusalem....	15.9	7.0	8.6	10.8	14.9	19.4
Hamadan. . .	11.6	— 1.4	0.0	3.1	8.1	12.8
Shiraz......	16.2	5.4	6.5	10.3	14.9	19.0
Fariman.....	11.6	0.1	1.5	4.7	9.4	15.2

STATION	J	J	A	S	O	N	D
Palermo. . . .	21.5	24.6	24.8	23.0	19.6	15.2	11.9
Athens......	24.4	27.3	26.6	23.5	19.4	14.1	10.5
Jerusalem....	21.3	22.9	23.0	21.3	19.1	13.3	9.4
Hamadan...	19.6	24.7	25.2	20.5	16.2	8.9	2.4
Shiraz......	22.5	26.1	25.5	22.0	18.6	14.4	9.4
Fariman....	20.5	22.7	21.9	18.6	13.7	8.0	3.2

The above table brings out some interesting facts regarding the Cs type of climate in the Mediterranean basin and in Iran. On the whole, the annual temperatures in Iran are considerably lower than the Mediterranean stations. Even Shiraz which is actually eight degrees nearer to the equator than Athens, has an annual temperature 6 degrees lower in value than that of the Greek capital. Winter conditions can be judged from the fact that in most of Iranian Cs stations, the January mean is around zero to 5 degrees centigrade whereas in the Mediterranean Basin they range between 5° and 10° C. There is a closer conformity in the summer temperatures between the two sets of stations, as can be seen from the comparison of July temperatures in the above table.

[1] Data for Palermo, Athens and Jerusalem from E. de Martonne's, *Traité de géographie physique*, vol. 1, Paris 1925, p. 302.

In summer, practically all the Cs stations in Iran record averages above 22° C as do most of the Mediterranean stations. Therefore the symbol «a» is added to the Cs and consequently they become Csa or typical Mediterranean stations.

The analogy ends, however, when the rainfall regime comes to the picture in the two areas. In the Mediterranean proper, winter rains decrease in amount as the warm season advances with the result that April, May and June, become progressively drier. In Iran the onset of spring and the rise in temperature cause a good deal of convectional rain as has been already discussed at some length in another chapter. Many Cs stations in Iran therefore record a major, or at least, a second maximum rainfall in the months that preceed the warmer part of the year. In other words, precipitation maximum is delayed to spring and early summer and symbol «x» of Koeppen's is added to a great number of stations and consequently the C climates of Iran can be conveniently divided to two subtypes, namely Csa and Csxa as already pointed out.

January is the coldest month in all stations included in this section except in Tabriz where over a twelve year period the average for this month is -1.4° C whereas the mean for February is -1.6°. Of all the stations Shiraz has the highest January mean of 5.4° C which is due to its latitudinal position. In all other stations the mean for the coldest month of the year varies between -1.4° and 1.2° C.

July is the hottest month of the year in Shiraz and Fariman but in the remaining stations August has an average of about one degree centigrade higher than the previous month.

Average monthly maximum and minimum figures are available for all the stations, and the study of such data indicates that temperatures above 40° C occur in all the stations during the summer months. Even in Sanandaj, at an elevation of 1,648 m., the mercury has once risen to above the 40° C level according to the existing data. More important from the practical point of view are the severe winter colds that can be experienced at most of the highland stations in Iran. In Shiraz, which is the most southerly and the warmest of all the stations under consideration, below zero temperatures are recorded every month from November to April inclusive. In more northern localities, the lowering of

temperature and the risk of frost to agriculture appears to be of longer duration still. All other stations have sub-zero records for seven months of the year and Fariman and Sanandaj have registered an absolute minimum of -23° C during the period of the present study.

The boundary between the BS and the C climates in Iran coincides approximately with the 30 centimeter isohyet line on the average annual precipitation map of the country (map No. 12) with the result that a great majority of the Cs stations receive more than 30 cm. of rainfall annually.

Generally speaking, precipitation in the Cs climates of Iran, increases from south to north and from lower to higher elevations. Shiraz, on the southern boundary of the Csa has an annual average of 336 mm. all of which falls between November and May. All through the Csa climate of Iran that extends approximately between Shiraz and Kermanshah, precipitation is mostly cyclonic in nature and therefore concentrates during the months when cyclonic activity is at its height. Shiraz, for instance, receives 222 mm. or 66 % of its annual precipitation during January, February and March. January is the rainiest month and in this month, Shiraz records 82 mm. or about 25 % of its annual average. In this respect, Shiraz, not only typifies the Csa climate of Iran, characterized by having a single maximum rainfall in the coldest month, but it also represents the rainfall regime of the surrounding BS area.

However, some stations such as Hamadan and Sanandaj (see Appendix), which draw more benefit from the winter depressions, show a clear double maximum; the first in January and the second in April. In such cases the first maximum is totally due to cyclonic precipitations of the winter season. The second maximum, however, can be attributed to convectional showers that are a common greature of the snowclad mountainsides during the spring and early summer months.

Summers are generally dry in all the Cs area of Iran and small figures of one to five millimeters shown in the appendix, often result from occasional showers that may fall once in a long period of time.

C Climate (Caspian Type)

The great importance of the Alborz mountain as a formidable climatic barrier has been indicated on a number of occasions throughout this study. It has been also pointed out that there is a great contrast in the physical and cultural landscape, as well as in human occupation and land use, on the two sides of this all important barrier. The coastal plain of the Caspian Sea and the northern slopes of the mountains that overlook this sea, are climatically so different from the rest of the country that climate can be considered the only geographical factor in producing such contrasting features in the narrow Caspian Littoral.

In the map of climatic provinces of Iran, prepared for the present study, the Caspian area stands out as a narrow belt that encircles the southern shores of this sea inside the political frontiers of Iran. The whole belt may not exceed 20,000 to 25,000 sq. km. in area which seems quite insignificant, in size, when compared with the wide extents of other types of climate already discussed in the previous pages. Nevertheless, this small area constitutes an important section of Iran in which neither the population density, nor the economic prosperity and agricultural potentiality, can be surpassed by any other area of similar size in the country. Here again the very existence of a dozen climatic stations (a very high intensity on Iranian standards) is an indication of its human importance for, it has been already hinted that in Iran climatic stations are generally associated with centers of population and are not, as a rule, established where they can be of great climatic or meteorological value.

This Caspian type of climate is best characterized by moderate temperatures, small annual and diurnal ranges, very high humidity, strong land and sea breezes and local winds and very heavy precipitation that falls not only during the cold season as is the general rule in Iran, but also in other seasons of the year. The combined result of the above mentioned conditions can be seen in the luxuriant subtropical forests that cover the northern slopes of the Alborz up to a height of 2,500 m.[1].

[1] Fisher (W. B.), *op. cit.*, p. 262.

In the Koeppen classification of climates the stations that fringe the coastlines of the Caspian Sea in Iran fall into two subtypes of Cfa and Cs′″a with the latter occupying most of the middle sections of the coastal plain and the former appearing predominantly to the southwest and, to a certain degree, in the southeast of the area.

February is the coldest month at all stations and the average for this month varies from 3.5° C in Astara to 7.0° C in Gorgan. The low figure for Astara is partly due to higher latitude and partly due to the station being nearer to the cold and frozen waters of the northern sections of the Caspian Sea. The high value for Gorgan is the result of its greater distance from the sea and also because it is situated in the open Turkeman plain that warms up rapidly under the direct rays of the sun. The fact that February is the coldest month of the year is due to the general retarding influence of the sea as already explained in another chapter.

August is the warmest month of the year. The mean for the warmest month of the year is about 26° C which is below the mean for the plateau stations and which clearly indicates the moderating effects of the Caspian.

The mildness of the temperature conditions along the Caspian coast has been already discussed in the chapter on temperature. Here it can be added that, on the whole, more moderate conditions prevail in the western sections than in the east. The highest record at Pahlavi, during the period for which data are available, is 35° C and the lowest -9° C (lowest for the entire coastal area too). In the eastern parts of the area, Gorgan has recorded an absolute maximum of 44° C which has nothing comparable in any other station along the coast.

The annual range of temperature is much lower than in the plateau stations. This is to be expected in a maritime climate such as the one under consideration. Generally speaking, the annual range for the whole area can be said to be about 20° C.

Precipitation which is the only factor in dividing the climates of the Caspian area into Cf and Cs′″ types, is very high, at least according to Iranian standards. The highest value for the annual precipitation comes from Pahlavi (2,089 mm.). Rainfall decreases from this station both

to the north and to the east. In the north, Astara, on the frontier between Iran and the U.S.S.R., receives 1,326 mm. whereas in the extreme south east, Gorgan records a total annual precipitation of 1,154mm. only.

The Cf, or to be more exact the Cfs″a, type of climate is found in two sections of the Caspian area, namely the southwest and the southeast regions as shown on map No. 18. The two regions are separated by a long belt that occupies the whole of the middle Caspian coast. This narrow belt receives less rainfall in summer and cannot therefore be included in the Cf type. Actually it has a Cs′″a type as indicated by the Koeppen symbols given to all the stations in the area.

In the west Cf is the predominant type that extends all the way from Astara to a little to the west of Ramsar. In width this Cf area is limited between the coastline on the one hand and the crest of the surrounding mountains on the other. In the lowland delta of the Sefid Rud, the Cf extends further inland [1].

The regime of precipitation appears to be the same in all the Cf region of the Caspian. Rain falls every month of the year but there is a clear concentration of precipitation in the cold months of the year and many stations receive their major maximum in the autumn months. Summer months are relatively dry but even in June and July, which are normally the driest months of the year, precipitation exceeds 30 mm. in most of the stations.

The following tables of monthly and seasonal distribution of precipitation will serve to illustrate the actual regime in the Cf climate.

STATION	J	F	M	A	M	J	J
Astara......	100	53	151	149	103	83	28
Pahlavi.	123	150	246	90	66	56	63
Lahijan......	162	123	118	80	58	46	54

[1] It should be noted here that there is a complete lack of climatic stations between the Caspian coast and the southern fotohills of the Alborz which face the interior of Iran. The position of the middle valleys of the Alborz is not therefore clearly known. The bounderies between the Cf and the Cs′″a climates on the one hand and those of the Csxa to the south on the other, are drawn more tentatively here than in the rest of the country.

STATION	A	S	O	N	D	Total
Astara......	34	175	180	214	92	1.362
Pahlavi.	133	286	393	251	232	2.089
Lahijan......	79	137	156	198	113	1.324

Seasonal Distribution of Precipitation at the above mentioned stations

STATION	Pahlavi		Astara		Lahijan	
	mms	%	mms	%	mms	%
Winter...........	519	26	304	22	403	30
Spring...........	212	10	335	24	188	14
Summer.	482	24	237	17	270	20
Autumn.	876	40	486	37	467	36
Year	2.089	100	1.362	100	1.324	100

In the eastern section of the Caspian littoral the Cf type which covers most of the delta plains of Gorgan, offers a somewhat different regime of precipitation as can be seen from the following data :

J	F	M	A	M	J	J	A	S	O	N	D	Total
89	70	86	108	28	30	47	61	218	117	187	113	1.154

A comparison of the above table with those just discussed for the western Cf sections brings out the following contrasts :

1 : The annual total is less in the east than in the west.

2 : Autumn is decisively the season for maximum precipitation in the eastern section.

3 : There is a clear spring maximum in the eastern section.

The two Cf areas of the Caspian type of climate are separated from each other by a narrow belt that is less fortunate in total precipitation and therefore cannot be classed as having a Cf climate. This is the zone marked as Cs′″a on the climatic map of Iran.

Precipitation occurs every month of the year but in summer months the average is below 30 mm. Summer aridity is more pronounced and the two rainy seasons are separated by a longer interval than in the Cf climates, as can be seen from the following table :

Monthly precipitation at selected stations in the Cs' " climates of Iran

STATION	J	F	M	A	M	J	J	A	S	O	N	D	Total
Ramsar....	66	58	82	64	46	23	34	37	176	209	316	85	1.196
Nowshahr..	102	67	73	79	20	25	24	47	215	176	136	176	1.167

Autumn and early winter months are the rainiest of all and some stations receive as much as 50 % of their annual total between October and January. This is a common feature of all the Caspian stations as has been indicated already, but it becomes more prominent in the Cs' "a stations which remain relatively drier during the rest of the year. There is a tendency towards a maximum in March or April but the period May to September is the period of lowest rainfall with the monthly means falling to below 30 mm. in many stations. The autumn maximum is due to cyclonic activity combined with the effects of the northerly and northeasterlies. There remains the summer minimum to be explained and for this purpose we must study the local conditions. Along the central shores of the Caspian, there is practically no coastal plain and in some cases, the foothills of the Alborz almost touch the sea. This is the case in Ramsar where the beautiful Spa Hotel, that looks like a gem against the background of the mountain forests, is only a walking distance from the sea. Under such circumstances, the land and sea breezes, which are responsible for producing most of the summer rains along the coast, do not develop so well as they do on extensive coastal plains. The latter get heated more rapidly because of their flat surface and thin vegetation cover and therefore conduce to stronger local winds and consequently higher precipitation. The steep and forest clad northern slopes of the Alborz do not result in ideal conditions for land sea breezes and hence the smaller amount of precipitation throughout the summer months.

D and E types of climate

The boundary of the D climate varies in elevation from place to place ; depending on the latitude and the general thermal conditions of the surrounding areas. The patches marked as having a D type of climate on map No. 18 on the climatic provinces of Iran, cannot, satisfactorily, be fitted within definite altitudinal ranges and therefore deserve individual attention.

Of the total land surface area of Iran probably about 40,000 sq. km. have a D type of climate. In the northwest province of Azarbaijan, Rezaiyeh, to the west of a lake by the same name, shows an average January temperature of -2.5° C. This station has an elevation of 1,300 m. and one has to climb another 100 m. only to arrive at the boundary of D climate where the coldest month will have a mean temperature of less than -3° C. The mountains behind Rezaiyeh, otherwise known as the Turkish frontier mountains, have therefore been marked as having a D climate.

Similarly, Tabriz, at an elevation of 1,360 m. has a January mean temperature of -1.4° C and a February average of -1.6° C. The sourrounding areas having an altitude of more than 1,750 m. are therefore included in the D type of climate.

Other patches of D climate shown on map No. 18 have been all delimited on the above lines and we need not discuss each of them separately. However, it is interesting to note that D climate can occur in Iran as far south as the 30° N latitude line. At Kerman (30°.30′ N) the mean January temperature is 5.3° C but to the south of this station some peaks of the Kuh-e-Hazar and Kuh-e-Lalezar, reach heights of over 4,400 m. The higher sections of these mountains therefore have a D climate.

Map No. 18 of the climatic provinces of Iran shows small patches of ET climate too. According to Koeppen's system of climatic classification when the mean temperature for the warmest month of the year falls short of 10° C the climate of the station concerned is considered to be an E type. In the ET subtype, the average for the warmest month of

the year should range from 0 to 10° C. In Iran there are some small patches of very high ground that exhibit the necessary qualifications for being classed as ET type of climate. These include the area surrounding the magnificent volcanic peak of Demavand to the north-east of Tehran. This mountain is permanently covered with snow in its higher sections and there are believed to be glaciers in its northfacing valleys. The existence of permanent snow brings the place automatically within the E type of climate for, only with monthly means ranging around 0° C can permanent snow or ice be found throughout the year. Similar conditions prevail around the volcanic peaks of Sabalan and, to a certain degree around Sahand, on the plateau of Azarbaijan. The latter two sections have therefore been included in the ET type of climate which altogether covers a very negligible portion of Iran's land surface.

APPENDIX I

KOEPPEN SYMBOLS

1.	A	Coldest month above 18°C.
	Af	Warm wet (no month below 6 cm.).
	Am	Short dry season.
	Aw	Dry period during low sun position (winter)
	As	Dry period during high sun position (summer)
	s' or w'	Rainy season shifted toward fall
	s" or w"	Rainy season interrupted by short dry period (two wet and two dry periods).
	g	Ganges type, warmest month in spring or early summer.
2.	B	Dry Climates :
	W	*Desert :* rainfall (cm.) below t (Centigrade) for winter rain. rainfall (cm.) below $t+14$ (C.) for summer rain. rainfall (cm.) below $t+7$ (C.) otherwise. winter rain 60 % or more during the six winter months. summer rain 70 % or more during the six summer months.

	S	*Steppe* same criteria but multiply with two; $2t$, $2(t+7)$, $2(t+14)$ For A climates always use summer formula
	h	year temperature above 18°C [1].
	k	year temperature below 18°C, warmest month above 18°C.
	k'	year temperature below 18°C, warmest month below 18°C.
	n	fog.
	n'	little fog but high humidity, summer below 24°C.
	n"	Same for summer 24°-28°C.
	n"'	Same for summer above 28°C.
3.	C	*Coldest month between* 18° *and* -3°*C* (sometimes 0° is used).
	f	no month below 3 cm. precipitation.
	s	month with most precipitation in winter has three times as much precipitation as month with least precipitation in summer.
	w	month with most precipitation in summer has ten times as much as driest month in winter.
	a	warmest month above 22°C.
	b	warmest month below 22°C but at least four months above 10°C.
	c	one to four months above 10°C, coldest above -38°C.
	d	coldest month below -38°C.
	i	difference between extreme months less than 5°C.
	t'	warmest season delayed into fall.
	x	precipitation maximum in spring or early summer.
4.	D	*Coldest month below* -3°*C*, *warmest above* 10°*C*. (use same criteria as described under C).
5.	E	*warmest months below* 10°*C*.
	ET	warmest month 0-10°C.
	EF	warmest below 0°C.

[1] It is recommended to use A, C and D instead of h and k.

APPENDIX II

CLIMATIC DATA OF IMPORTANT STATIONS

Temperatures in centigrade, Rainfall in millimeters. All decimals dropped out from temperature figures.

Name of Station	Koeppen Symbol	Latitude	Longitude	Elevetion (Ms.)	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
1. Abadan	BWsa(h)	30° 32′	48° 17′	6	11°	14°	19°	26°	32°	34°	36°	35°	32°	27°	20°	14°	25°
					39	18	22	8	11	—	—	—	—	8	25	38	169
2. Ahar	Csx″a	38° 27′	47° 07′	1,459	—1°	0	0	6°	10°	16°	22°	24°	20°	14°	8°	4°	10°
					15	12	41	41	85	62	13	—	7	46	36	11	369
3. Ahwaz	BWsa(h)	31° 20′	48° 40′	66	15°	12°	17°	21°	29°	35°	36°	36°	34°	30°	22°	15°	25°
					45	20	34	9	5	—	—	—	—	—	27	50	190
4. Arak	Csx″a	34° 07′	49° 37	1,880	0°	1°	5°	11°	16°	23°	26°	26°	22°	17°	10°	4°	13°
					59	35	46	64	59	—	—	—	—	—	18	50	331
5. Ardabil	Csxa	38° 15′	48° 18′	1,570	—2°	—1°	2°	7°	12°	17°	20°	20°	17°	12°	7°	2°	9°
					22	27	37	18	51	16	5	7	8	20	25	25	265
6. Astara [1]	Cfs′″a	38° 27′	48° 52′	—20	5°	4°	6°	10°	16°	22°	27°	27°	23°	17°	12°	7°	15°
					100	53	151	149	103	83	28	34	175	180	214	92	1362
7. Babol [1]	Cs′″a	36° 14′	52° 42′	80	7°	7°	8°	12°	17°	22°	22°	26°	28°	21°	16°	10°	16°
					134	128	55	38	42	18	45	81	80	125	81	120	947
8. Borujerd	Csxa	35° 53′	48° 55′	1,670	1°	1°	5°	8°	13°	18°	23°	23°	22°	16°	12°	4°	12°
					82	72	117	130	42	—	—	—	—	—	40	48	531
9. Bushehr	BWsa(h)	28° 58′	50° 50′	10	14°	15°	18°	23°	28°	30°	32°	32°	30°	26°	21°	19°	24°
					69	38	32	8	1	—	—	—	—	4	42	62	246
10. Gorgan	Cfs′″a	36° 40′	54° 36′	116	8°	7°	8°	13°	18°	23°	26°	27°	25°	20°	15	9°	16°
					89	70	86	108	28	30	47	61	218	117	187	113	1154
11. Hamadan	Csxa	34° 47′	48° 22′	1,860	1°	0°	3°	8°	13°	19°	24°	25°	20°	16°	9°	2°	12°
					60	50	67	85	63	4	—	—	1	3	38	33	404
12. Iranshahr	BWsa(h)	27° 13′	60° 42′	593	16°	17°	21°	26°	30°	36°	37°	36°	33°	32°	26°	17°	24°
					15	52	—	—	14	—	10	26	—	—	—	—	117 [2]
13. Ispahan	BSCsa(k)	32° 40′	51° 44′	1,550	4°	5°	8°	13°	17°	23°	27°	26°	23°	17°	13°	7°	15°
					29	26	25	20	27	2	—	—	—	—	10	27	166
14. Jask	BWAsa	25° 45′	57° 45′	4	19°	20°	23°	26°	29°	32°	33°	32°	31°	28°	24°	21°	26°
					31	24	19	5	—	—	—	—	—	4	5	30	120
15. Karaj	BSCsa(k)	35° 47′	51° 00′	1,300	1°	3°	6°	13°	16°	22°	25°	25°	22°	16°	11°	5°	14°
					30	32	45	47	38	2	1	1	—	4	18	20	238

[1] Precipitation figures after H. Bobek.

[2] Summer averages resulting from three monthly falls (probably of monsoonal origin) as follows; May 1948, 58 mms.; July 1943, 42 mms. and August 1944, 104 mms.

APPENDIX II (*continued*)

CLIMATIC DATA OF IMPORTANT STATIONS

Temperatures in centigrade, Rainfall in millimeters. All decimals dropped out from temperature figures.

Name of Station	Koeppen Symbol	Latitude	Longitude	Elevation (Ms.)	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
16. Kerman	BWCsa(k)	30° 03′	57° 02′	1,650	5°	7°	11°	16°	23°	27°	29°	26°	25°	20°	13°	4°	17°
					35	32	38	26	16	—	—	—	—	—	2	19	168
17. Kermanshah	Csa	34° 19′	47° 02′	1,472	1°	2°	5°	10°	16°	23°	26°	29°	23°	19°	11°	5°	14°
					45	66	62	31	58	—	—	—	10	—	40	20	332
18. Khoy	Csxa	38° 25′	44° 58′	1,370	—2°	—2°	2°	9°	15°	20°	25°	25°	21°	15°	8°	3°	12°
					19	18	33	89	59	44	17	5	2	17	37	7	347
19. Lahijan	Cfs'a	37° 12′	50° 00′	20	8°	7°	8°	13°	18°	23°	25°	26°	24°	20°	15°	10°	17°
					162	123	118	80	58	46	54	79	137	156	198	113	1324
20. Maragheh	Csxa	37° 22′	46° 16′	1,618	—2°	—1°	1°	7°	14°	20°	25°	26°	21°	16°	9°	3°	12°
					47	50	57	65	77	16	—	—	—	10	24	22	368
21. Marand	Csx''a	38° 26′	45° 46′	1,462	—3°	—2°	1°	7°	14°	16°	23°	24°	20°	12°	7°	1°	10°
					21	18	22	27	80	55	—	2	14	33	3	36	311
22. Mash'had	BSCsa(k)	36° 17′	59° 38′	940	1°	2°	7°	12°	19°	24°	28°	27°	23°	16°	11°	4°	14°
					33	30	40	23	36	10	—	—	—	3	13	20	208
23. Nowshahr	Cś''a	36° 36′	51° 46′	—26	7°	5°	7°	8°	14°	18°	24°	24°	20°	18°	12°	9°	14°
					102	67	73	79	20	52	24	47	215	176	136	176	1167[1]
24. Pahlavi	Cfś''a	37° 28′	48° 52′	—26	7°	6°	7°	13°	17°	22°	25°	26°	24°	19°	14°	10	15°
					123	150	246	90	66	56	63	133	286	293	251	232	2089
25. Rafsenjan	BWsa(h)	30° 24′	56° 02′	1,597	5°	6°	11°	16°	22°	28°	31°	30°	26°	21°	14°	8°	18°
					20	8	7	5	11	—	—	—	2	—	—	6	59
26. Ramsar	Cś''a	36° 55′	50° 53′	—26	9°	8°	9°	12°	15°	21°	26°	26°	25°	21°	16°	12°	17°
					66	58	82	64	46	23	34	37	176	209	316	85	1196
27. Rasht	Cfś''a	37° 16′	49° 36′	10	8°	4°	8°	13°	20°	26°	29°	28°	24°	20°	16°	9°	17°
					73	230	79	57	55	53	30	48	135	110	153	85	1108
28. Rezaiyeh	Csxa	37° 35′	45° 04′	1,300	—2.5°	—2°	2°	8°	11°	19°	23°	23°	19°	14°	8°	2°	10°
					49	39	52	92	75	21	8	3	3	12	32	41	427
29. Sanandaj	Csxa	35° 20′	45° 53′	1,648	1°	1°	4°	10°	15°	23°	26°	27°	24°	19°	12°	6°	14°
					96	49	87	102	72	3	—	4	—	3	24	50	490
30. Shahi	Cś''a	36° 28′	52° 54′	20	7°	8°	8°	11°	18°	23°	26°	27°	26°	20°	15°	8°	16°
					68	38	111	51	33	7	15	16	37	108	98	36	618*

[1] Precipitation figures after H. Bobek.

APPENDIX II (*continued*)

CLIMATIC DATA OF IMPORTANT STATIONS

Temperatures in centigrade, Rainfall in millimeters. All decimals dropped out from temperature figures.

(1) Precipitation figures after H. Bobek.

Name of Station	Koeppen Symbol	Latitude	Longitude	Elevation (Ms.)	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
31. Shahsavar	Cś''a	36° 46′	50° 52′	20	7°	6°	7°	11°	17°	23°	26°	27°	24°	20°	16°	10°	16°
					88	90	239	87	21	6	—	11	148	403	307	113	1511[1]
32. Shiraz	Csa	29° 36′	52° 34′	1,500	5°	6°	10°	15°	19°	22°	26°	25°	22°	19°	14°	10°	16°
					82	78	62	33	4	19	—	—	—	—	7	55	336
33. Tabriz	Csxa	38° 46′	46° 17′	1,360	—1°	—2°	2°	8°	15°	20°	25°	26°	20°	16°	9°	3°	12°
					17	26	32	48	55	17	11	2	5	19	20	31	283
34. Tehran	BSCsa(k)	36° 04′	51° 25′	1,200	3°	5°	8°	15°	20°	27°	31°	30°	27°	21°	14°	7°	17°
					45	33	32	32	25	—	—	—	—	—	30	27	226
35. Yazd	BWsa(h)	31° 16′	52° 39′	1,200	6°	7°	11°	16°	23°	30°	33°	31°	28°	22°	16°	10°	19°
					33	24	12	8	20	—	—	—	—	—	23	6	126
36. Zabol	BWsa(h)	31° 03′	60° 30′	516	1°	9°	13°	20°	24°	28°	29°	30°	27°	22°	16°	10°	20°
					17	26	14	10	6	—	—	—	—	—	—	10	83
37. Zahedan	BWsa(h)	29° 30′	60° 52′	1,370	6°	8°	13°	17°	23°	29°	31°	30°	24°	19°	13°	8°	18°
					9	40	13	9	—	—	—	—	—	—	—	5	76

SELECTED BIBLIOGRAPHY

1. Banerji, H. C. The Meteorology of the Persian Gulf and Makran, *Central Publication,* Calcutta, 1931.
2. Bauer, G. Luftzirkulation und Niederschlagsverhaeltnisse in Vorderasien, *Beitraege zur Geophysik,* vol. 45, 1935, pp. 381-548.
3. Benner, C. P. & Gibbons, J. J. Climatology Report on Iran, Iraq and Baluchistan, *California Institute of Technology, Military Climatology,* vol. 1, 1942.
4. Biel, Erwin R. Climatology of Mediterranean Area, *University of Chicago Institute of Meteorology, Miscellaneous Reports,* No. 13, 1944.
5. Blair, Thomas A. Climatology, *General and Regional,* New York, 1942.
6. —— Weather Elements, New York, 1937.
7. Bobek, Hans. Die Naturalischen Waelder und Gehalzfluren Irans, Bonn University, *Geogr. Inst.,* 1951.
8. —— Die Verbreitung des Regenfeldbandes in Iran, Geographische Studien, *Geogr. Inst. der Universitaet Wien,* 1951.
9. —— Beitraege zur Klima-okologischen Gliederung Irans, Erdkunde Archiv fuer Wissenschaftliche Geographie, Band VI, Heft 2/3, June 1952, pp. 65-84.
10. Boesch, Hans H. Das Klima des Nahen Ostens auf Grund neuren Beobachtungsmaterials der Iraq Petroleum Company aus den Jahren 1935-1938, *Naturforschende Gesellschaft in Zuerich,* Vierteljahrsschrift, vol. 1941, pp. 8-66.
11. British Admiralty, «Naval Intelligence Division», *Persia,* London, Sept. 1945.
12. —— «The Climate of the Eastern Mediterranean», London, 1916.
13. British Air Ministry. Aviation Department, *Meteorological Report on Persia,* Report No. 33, 1946.
14. British Hydrographic Office. Persian Gulf Pilot, 9th edition, London, 1942.

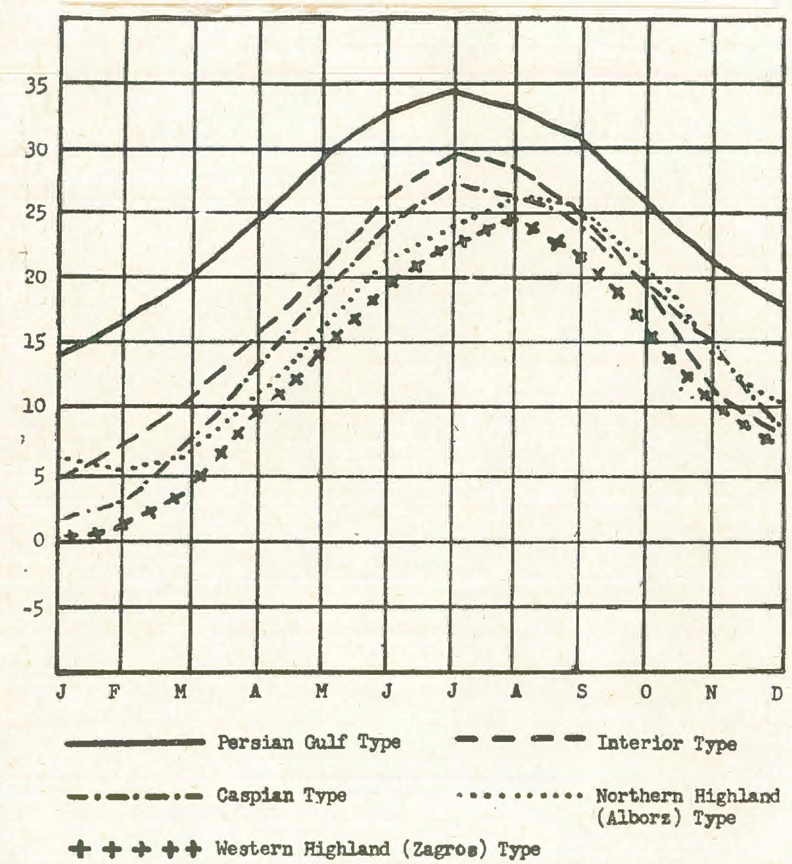
Selected Bibliography (*continued*)

15. Conrad, Victor. The Climate of the Mediterranean Region, *Bull. Amer. Meteor. Soc.,* 1943, pp. 127-145.
16. —— Methods in Climatology, *Harvard University Press,* 1946.
17. De Martonne, E. Regions of Interior Basin Drainage, *Geog. Rev.,* 1927, pp. 397-444.
18. —— Traité de Géographie Physique, vol. I, Paris, 1925.
19. Fisher, W. B. The Middle East, London, 1950.
20. Fletcher, L. R. General Climatic Conditions in Iraq and Iran, *U. S. Weather Bureau, Special Report* No. 164, 1942.
21. Hann, J. Handbook of Climatology, translated by R. D. Ward, Part 1, New York, 1903.
22. Kendrew, W. G. The Climate of the Continents, Oxford, 1922.
23. Koeppen, W. & Geiger, Handbuch der Klimatologie, vol. I, Pt. C., Berlin, 1936.
24. Lyons, H. G. The Winter Climate of the Eastern Mediterranean, Roy. Met. Soc., Quarterly Jour., vol. XLII, April, 1916.
25. Miller, Austin. Climatology, New York, 1943.
26. Overseas Consultants Inc. Report on Seven Year Development Plan Organization of the Government of Iran, vol. 3, New York, 1949.
27. Reed, W. W. Temperatures in Asia, *U. S. Weather Bureau Publication,* 1931.
28. —— The Distribution of Precipitation over the Earth, *U. S. Weather Bureau Publication.*
29. Smithsonian Institute. Miscellaneous Collections, vol. 35, 1893, vol. 90, 1934 and vol. 79, 1927 (*Meteorological Tables*).
30. Stenz, Ed. The Climate of Afghanistan, its Aridity, Dryness and Divisions; *Polish Institute of Arts and Sciences in America,* New York, 1946.
31. Stratil Sauer, G. Die Sommerstuerme Suedost-Irans, *Archiv fuer Meteorologie, Geophysik und Bioklimatologie,* Serie B, Wien, 1952, pp. 133-53.
33. Trewartha, G. T. An Introduction to Weather and Climate, New York, 1943.
34. U. S. Weather Bureau. Climatic Statistics for Ahwaz, southwestern Iran, publication No. 42, 1947.
35. Climatic Statistics for Kermanshah, publication No. 37, 1942.
36. Climate of Southwest Asia, Prepared by the Stat. Div., *U. S. W. B. in cooperation* with the *Weather Information Branch Headquarters,* AAF., Washington, D. C., 1945.
37. Ward, R. D. The Climates of the United States, Boston, 1925.
38. Weikmann, L. Zum Klima der Tuerkei, Ergebnisse dreijaehriger Beobachtungen, 1915-1918.

GRAPHIC REPORTER ON CHAPTER IV :

« Temperature types of thermal provinces of Iran »

see p. 232.



الدكتورة دولت صادق : مورفولوجية دمشق

موقع دمشق الجغرافى فى غاية الأهمية ، إذ تقع عند ملتقى عدة طرق رئيسية تصلها بشمال سوريا والعراق وبلاد العرب وساحل البحر الأبيض ومصر . أما من ناحية الموقع الاستراتيجى فهى ليست مدينة حصينة من الدرجة الأولى ، لأنها مفتوحة ، وتطل مباشرة على الصحراء من الناحية الشرقية .

ولدراسة تطور مدينة دمشق ونموها ندرس أولا دمشق القديمة ، ثم دمشق الرومانية ، ودمشق الحديثة . ولو أن البقايا القديمة محدودة إلا أن هناك عوامل جغرافية حتمت على المدينة أن تحتفظ بشكلها القديم ، فمثلا شكلها العام المستطيل الذى يمتد على الضفة اليمنى لنهر بردى . كذلك لا تزال المدينة تحتفظ بطابعها الشرق القديم من ناحية التخصص فى الصناعة فى احيائها المختلفة . ولا يزال بها أيضاً عدد من الشوارع القديمة الضيقة التى تساعد على وجود الظل أيام الصيف ، كما كانت تسهل الدفاع وقت الحرب .

أما دمشق الحديثة فقد نمت واتسعت ، وامتد معظمها على سفوح الجبال المحيطة بها . ودمشق الحديثة تختلف عن دمشق القديمة من حيث الشوارع والمبانى . فمثلا حى المهاجرين الجديد يمتاز بالشوارع الواسعة ذات الأشجار الضخمة على الجانبين والمبانى العالية .

وتمتاز دمشق بصبغتها الدينية ، فبها معابد للأديان الثلاثة ومن أشهر معالمها الجامع الأموى . وربما كان لموقع دمشق على طريق الحج القديم أثر هام فى كونها مدينة مقدسة .

الدكتور محمد ابراهيم حسن : الاستغلال الزراعى فى منخفض الفيوم

فى هذا المقال تعرض الباحث لنظام الاستغلال الزراعى فى المنخفض ، واعتمد فى دراسته التحليلية على دراسة المقومات الطبيعية التى تتحكم فى نوع الاستغلال الزراعى . هذا فضلا عن مناقشة الدورات الزراعية .

وعلى ضوء هذه الاسس قسم المنخفض إلى الاقاليم الزراعية الآتية :

١ – نطاق الأرز والحبوب : ويبدو فى شريط ضيق يمتد على طول معظم الشواطىء الجنوبية لبحيرة قارون . ويعتبر الأرز المحصول الرئيسى للدورة الزراعية فى هذا الاقليم ، وذلك لما تتميز به الأراضى هنا من وجود بعض الأملاح ، وهو يزرع فى هذه الجهات كوسيلة لاصلاح الأرض نظراً لما تحتاج إليه زراعة الأرز من رى وافر وصرف جيد .

٢ – نطاق القطن والحبوب : ويقع إلى الجنوب من الاقليم السابق ويسود معظم المنخفض . ويعد القطن هنا أهم غلات الدورة الزراعية ، ويليه الذرة والبرسيم والقمح والأرز .

٣ – نطاق الخضر والفاكهة : ويظهر حيث تسود التربة الطفلية قرب بعض المدن والجزر الرملية كما يبدو من خريطة الاستغلال الزراعى .

٤ – مناطق التوسع الزراعى : وتتمثل فى بعض الأراضى المنخفضة الملحية إلى الجنوب مباشرة من بحيرة قارون ، وحول المستنقعات فى اقليم الغرق جنوب غرب الفيوم . هذا وتظهر بعض الجزر الرملية المرتفعة قليلا ، وذلك إلى الجنوب من طامية ، ومطرطارس وفى منخفض الغرق . ويمكن استغلال هذه الجهات إذا توفرت المياه اللازمة للرى مع العناية بنظام الصرف .

والخلاصة أن اقليم الفيوم فى حاجة ماسة إلى التوسع فى شبكة المصارف الحقلية حتى ينخفض مستوى الماء الباطنى . هذا فضلا عن التوسع فى استخدام الأسمدة ، واتباع دورة زراعية يكون من أهم صفاتها ظهور فترة الشراقى حيث تستريح الأرض وتجدد خصوبتها ونشاطها .

و ١٩٥١ . كما أورد الخواص الطبيعية لهذه المياه المعدنية وفائدتها فى معالجة بعض الأمراض . وأشار المؤلف إلى ينابيع معدنية أخرى عرفت قديماً .

وفى نهاية المقال أشار المؤلف إلى مصدر المياه الكبريتية والمعدنية وأوضح علاقتها بالفوالق الموجودة بمنطقة حلوان ، ورجح أن يكون الحجر الرملى النوبى هو مصدر هذه المياه .

الدكتور محمد بهى الدين الحفنى : أهمية الشرق الأوسط العالمية

الشرق الأوسط اصطلاح اقليمى اشتركت فى صياغته بريطانيا والولايات المتحدة الامريكية أثناء الحرب العالمية الثانية ، ولو أن تحديده يختلف بناء على مصالحهما ، فمالطة والسودان مثلا تدخلان فى التحديد البريطانى ، وتركيا وباكستان فى الاعتبار الامريكى . ويضم الشرق الأوسط ما بين ليبيا وايران مزايا من حيث الموقع والقواعد الاستراتيجية والثروة البترولية مما جلب إليه اطماع الدول العظمى ، بريطانيا والولايات المتحدة ثم الاتحاد السوفييتى . وتلخص هذه المزايا فى : المركز المتوسط بين ثلاث قارات ، الطريق البحرى بين أوروبا وما وراء المحيط الهندى ، البسفور والدردنيل ، قناة السويس ومضيق باب المندب ، الهلال الخصيب ، ثم الخليج الفارسى . وقد كانت هذه المزايا دافعا لامتداد نفوذ بريطانيا إلى الاقليم بمثابة حلقة الوصل إلى مجالها الحيوى وراء المحيط الهندى . وتسجل احداث القرنين الثامن عشر والتاسع عشر كيف حققت بريطانيا هذا الهدف ، وكان من الطبيعى وهى تتحكم فى قواعد الشرق الاوسط الاستراتيجية أن تنال اعتبارات سياسية مع دوله التى تشكلت عقب الحرب العالمية الأولى وتضمن قواعد حربية فى بعضها .

وقد أضاف البترول إلى الشرق الأوسط حديثاً أهمية عظمى مما ترتب عليه تكالب الشركات الأجنبية ، وعلى رأسها الامريكية والبريطانية ، لاستغلال الموارد بناء على عقود لآجال تمتد حتى نهاية القرن العشرين . ويمكن تقدير أهمية الاقليم بالاشارة إلى أنه يحتل المكانة الثانية فى العالم فى الانتاج والمكانة الأولى فى الصادرات والرصيد . ويمد البترول معظم حاجات الدول الأوروبية والاسيوية

مما يزيل هذا العبء عن الموارد الامريكية . وبينما يقع استغلال البترول فى أيدى الدول الغربية ، يحتفظ الاتحاد السوفييتى بحقوق استغلال فى شمال ايران حصل عليها تحت ضغط الاحتلال عقب الحربين العالميتين الأولى والثانية

وهكذا أصبح الشرق الأوسط ملتقى أطماع خارجية ، فعلاقته السياسية والاقتصادية بدول الغرب الكبرى ، وموقعه على حدود الاتحاد السوفييتى ، يحصران الاقليم بين هاتين القوتين .

الدكتور محمد أحمد سليم : مشروع السد العالى

أشار المؤلف إلى مشكلة سرعة تزايد السكان فى مصر منذ بداية القرن التاسع عشر مع ضيق المساحة الصالحة للزراعة . ويتلخص علاج المشكلة فى زيادة المساحة المنزرعة ، مع محاولة وقف زيادة السكان . وقد وضع مشروع السد العالى المزمع إنشاؤه إلى الجنوب من أسوان لتحقيق الشق الأول من العلاج ، فالخزانات الحالية عند أسوان وجبل الأولياء لا تخزن من الفيضانات العالية ما يساعد على استكمال النقص فى الفيضانات المنخفضة كما أن صغر حجمها نسبياً يجعل من الضرورى تأخير البدء بالتخزين حتى تقل كميات الطمى فى النهر خوفاً من زيادة الترسيب فى قاع الخزان .

ثم انتقل المؤلف إلى مزايا السد العالى والنتائج الاقتصادية التى ستترتب عليه من زيادة كبيرة فى الرقعة المنزرعة ، وتلافى أخطار الفيضانات العالية ، وضمان تصريف مائى منتظم طوال كل شهور السنة مهما كانت درجة ارتفاع الفيضان أو انخفاضه ، وتوليد الكهرباء ، وصناعة السماد . أما ترسيب الطمى فى الخزان فلن يتجاوز ٣٠ مليار متر مكعب فى ٥٠٠ سنة على حين أن سعة الخزان تقدر بنحو ١٣٠ ملياراً .

وتكلم المؤلف عن تصميم الخزان وتكاليفه ، وانتهى إلى أن تكاليفه لا تستحق الذكر إلى جانب مزاياه .

يوافق المؤلفان على الافتراض القائل بأن منخفض الواحات قد تكون بجانب الخطوط التركيبية . وقد لوحظ مظهران لتغير الطبقات : أحدهما بشكل انتفاخات وأحواض فى الجزء الجنوبى من البلاد ، والثانى بشكل تشوهات تكتونية هى عبارة عن مجموعات من المنحدرات المزدوجة الجهات والقباب والتجاويف . وخير مثال لها هو منحدر أبى رواش . والتركيبات فى هذين المظهرين تنتهى مع مضى الزمن إلى نتوءات وتدفقات بازلتية .

أما منخفضات الواحات فإن التشوهات فيها أوسع مدى بخاصة فى المنطقة الجنوبية المنتفخة ، وفى المنطقة الشمالية ذات الثنايا والاعوجاجات .

ويعتقد المؤلفان أن تحلل تركيب أجزاء المواد الحجرية حدث بفعل المياه الملحة . أما الرياح الرملية فأثرها ضئيل فى احداث الحفر . وفى رأيهما أن الظروف الصحراوية مسيطرة على مصر منذ العصر الميوسينى .

الأستاذ هـ . شورمان : تاريخ ما قبل الكامبرى فى منطقة خليج السويس

عرض المؤلف خلاصة أبحاثه عن تاريخ صخور ما قبل الكامبرى فى منطقة خليج السويس فى صورة جدول استراتجرافى ورسوم توضيحية ، وقسم الزمن إلى عصور متتابعة تنفصل عن بعضها البعض بطريقة عدم التناسق نتيجة لتعرية صخور العصر اللاحق .

الدكتوران رشدى سعيد ونصرى شكرى : الشواطىء القديمة فى مصر — الجزء الأول الزمن الباليوزوى

عرض المؤلفان لتتابع بعض الحوادث الجيولوجية على مصر خلال الزمن الباليوزوى واستنتجا بعد دراسة رواسب العصور المختلفة الظاهرة وما عرف منها تحت السطح خلال عمليات الحفر عند البحث عن البترول أن مصر لا بد قد ظلت أرضاً يابسة حتى ابتداء العصر الكربونى حينما غمر جزءها الشمالى الشرقى بحر ربما كان امتداداً للذراع الباسيفيكى الذى غمر فلسطين فى العصر الكامبرى . كما استنتجا من هذه الدراسة قدم الاتجاهات التكتونية

الاريترية والسورية التى ظهرت بشكل واضح فى الازمان التى تلت الزمن الباليوزوى .

الأستاذ محمود ابراهيم عطيه : مساهمة فى دراسة ينابيع حلوان الكبريتية والمعدنية

ابتدأ المؤلف مقاله بعرض تاريخى لمدينة حلوان وعيونها الكبريتية وحماماتها منذ بدء القرن التاسع عشر (١٨٠٥ — ١٨٤٨) إلى الآن . ثم تكلم عن موقع حلوان الصحراوى الذى يتميز بشتاء قصير (ديسمبر إلى فبراير) يتبعه فترة (مارس إلى مايو) انتقال إلى الجو الصيفى (يونيه إلى سبتمبر) الذى تعقبه فترة باردة (اكتوبر ونوفبر)

وأوضح المؤلف تضاريس منطقة حلوان ثم تكلم عن التكوينات الجيولوجية للمنطقة ، وهى تكوينات الايوسينى المتوسط ، والايوسينى الأعلى ، والبليو — بليوستوسينى ، والبليوستوسينى ، والحديث ، وأخيراً طمى النيل . ثم تحدث عن التركيب الجيولوجى للمنطقة وما بها من فوالق وأهمها مجموعة الفوالق التى تتجه من الشمال الغربى إلى الجنوب الشرقى ، ثم المجموعة التى تتجه من الشرق إلى الغرب .

وذكر المؤلف أن الينابيع الكبريتية فى حلوان معروفة منذ عام ١٨٥٠ ، وأعطى التحاليل القديمة والحديثة لمياهها الكبريتية . كما أورد جدولا يلخص أبحاثاً عن بعض آبار حلوان وعيونها ، استخلص منه أن ينابيع حلوان الكبريتية تنحصر فى الجزء الجنوبى والجنوبى الغربى لمنطقة حلوان ، وأن الينابيع المعدنية تنحصر فى الجزء الشمالى الغربى . وأورد المؤلف الخواص الطبيعية والفوائد الطبية والعلاجية للمياه الكبريتية ودرجة حرارتها ، واستنتج من ذلك أن هذه المياه صادرة من أعماق الأرض . كما أورد التصرف اليومى لهذه الينابيع .

وأوضح المؤلف كيفية ظهور الينبوع المعدنى الجديد شمال غربى حلوان ، وأثبت تحاليل مياهه فى أطواره المختلفة منذ ظهورها إلى أن أقيمت المنشآت الحالية حوله ، ومنها ثلاثة تحاليل كاملة أجريت فى السنوات ١٩٣٩ و ١٩٤٠

ملخص المحاضرات

الدكتور حسان محمد عوض : « البدمنت » — مشكلة من مشكلات مورفولوجية الاقاليم الجافة

يعالج المؤلف فى بحثه مورفولوجية الشكل الطوبوغرافى المعروف باسم « البدمنت » ، والبدمنت عبارة عن سهول تحاتية صخرية تتكون فى العادة عند قدم الجبال العالية فى الجهات الجافة وشبه الجافة .

وقد عنى المؤلف بعرض النظريات المختلفة فى تفسير هذه الظاهرة ، كما عنى بتحليل عوامل التشكيل المختلفة المرتبطة بهذه النظريات . ثم درس مختلف العوامل التى تؤثر فى هذا الشكل وفى طبيعة تطوره وفى خصائصه ، وأهم هذه العوامل ما يأتى : —

أولا — نوع الصخر والبنية الجيولوجية : فشكل البدمنت وتطوره يتأثر بهما كما تتأثر بهما عوامل التشكيل نفسها .

ثانياً — العوامل المناخية : وهى تحدد عامل أو عوامل التعرية المسئولة — أكثر من غيرها — عن تكوين البدمنت .

ثالثاً — المستوى القاعدى وطبيعته ، فهناك حالات متعددة للمستوى القاعدى يظهر تأثيرها فى الكيفية التى تتكون بها أشكال البدمنت .

وفى القسم الأخير من المقال أشار المؤلف إلى مراحل التطور المختلفة التى تمر بها البدمنت والشكل الذى يتخذه قطاعها فى كل مرحلة .

ج . كنيتش ، م . يللوز : ملاحظات عن أصل منخفض الواحات المصرية

نشر الأستاذ بفانتستايل أخيراً بحثاً عن أصل منخفض الواحات المصرية . وقد ظهر هذا المقال عند ما أتم المؤلفان بحثهما عن التركيبات الخطوطية لحوض النيل . ولما كانت النتائج التى وصل إليها الأستاذ بفانتستايل فى نفس الموضوع جديرة بالاهتمام فقد رأى المؤلفان أن يستخلصا من المقارنة رأيهما الموجز فيما يلى :

مجلة

الجمعية الجغرافية المصرية

المجلد الثامن والعشرون

سبتمبر ١٩٥٥

Le Caire : Imprimerie de l'Institut français d'Archéologie orientale.

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